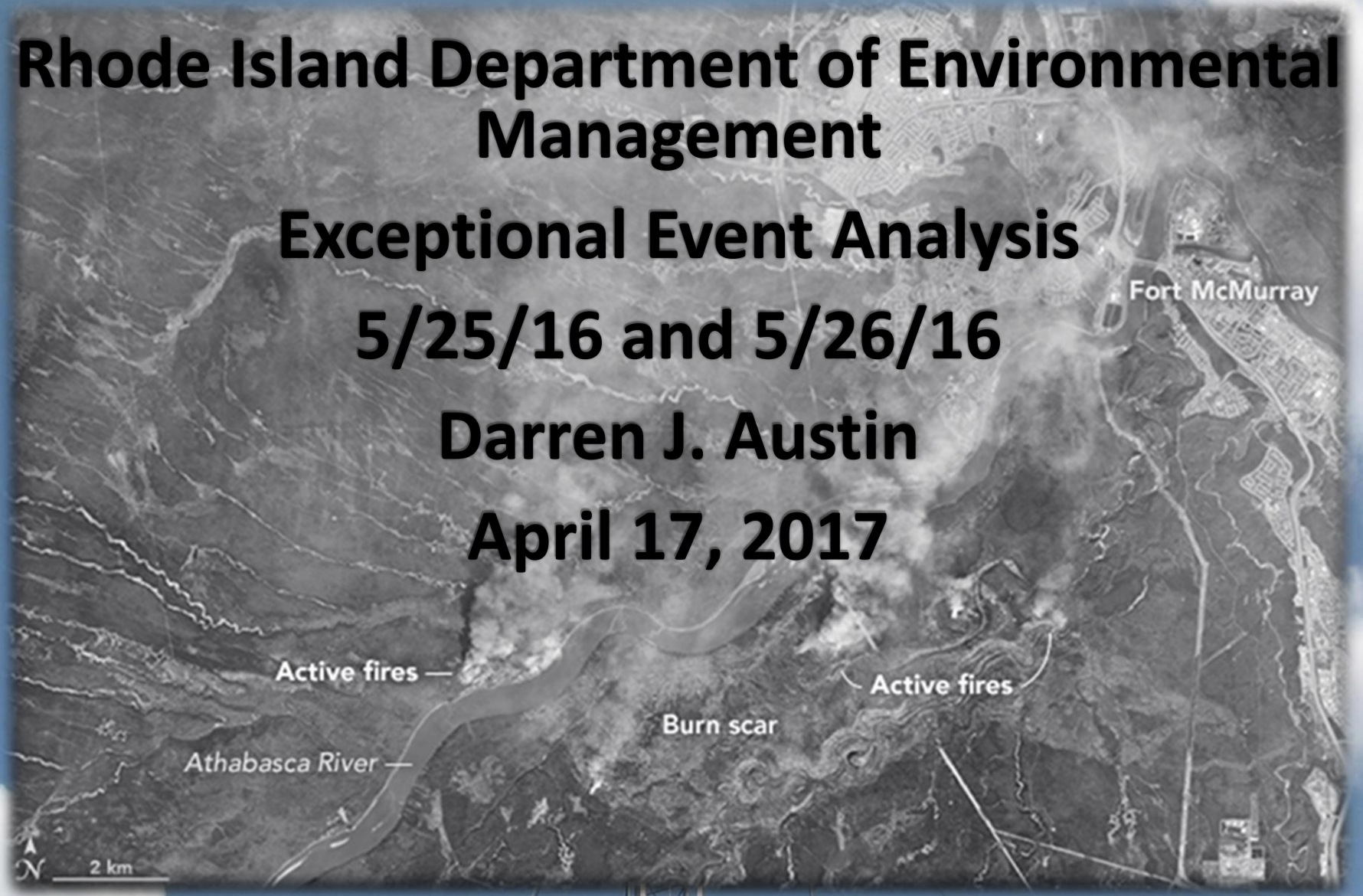
Rhode Island Department of Environmental Management

Exceptional Event Analysis

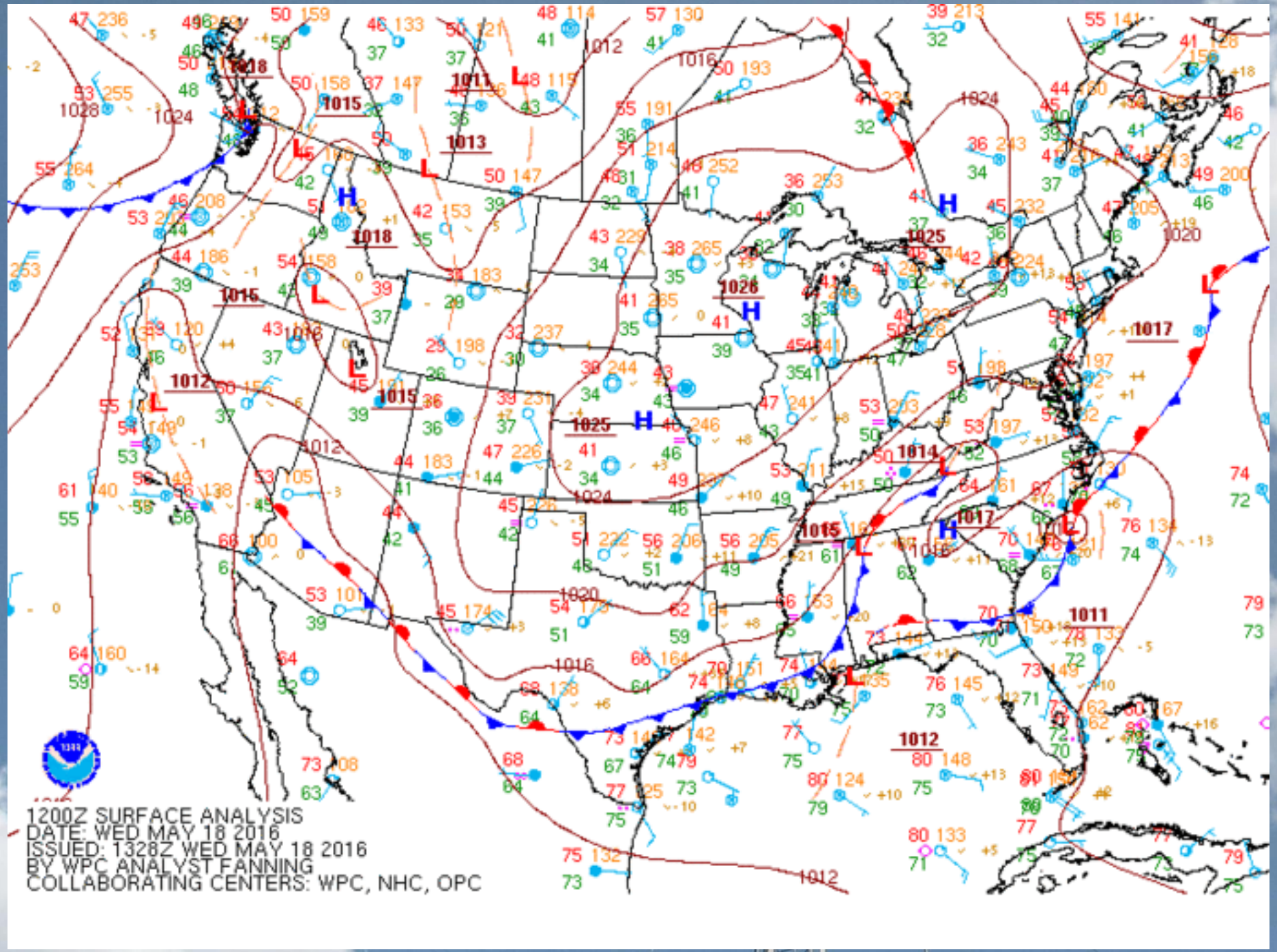
5/25/16 and 5/26/16

Darren J. Austin

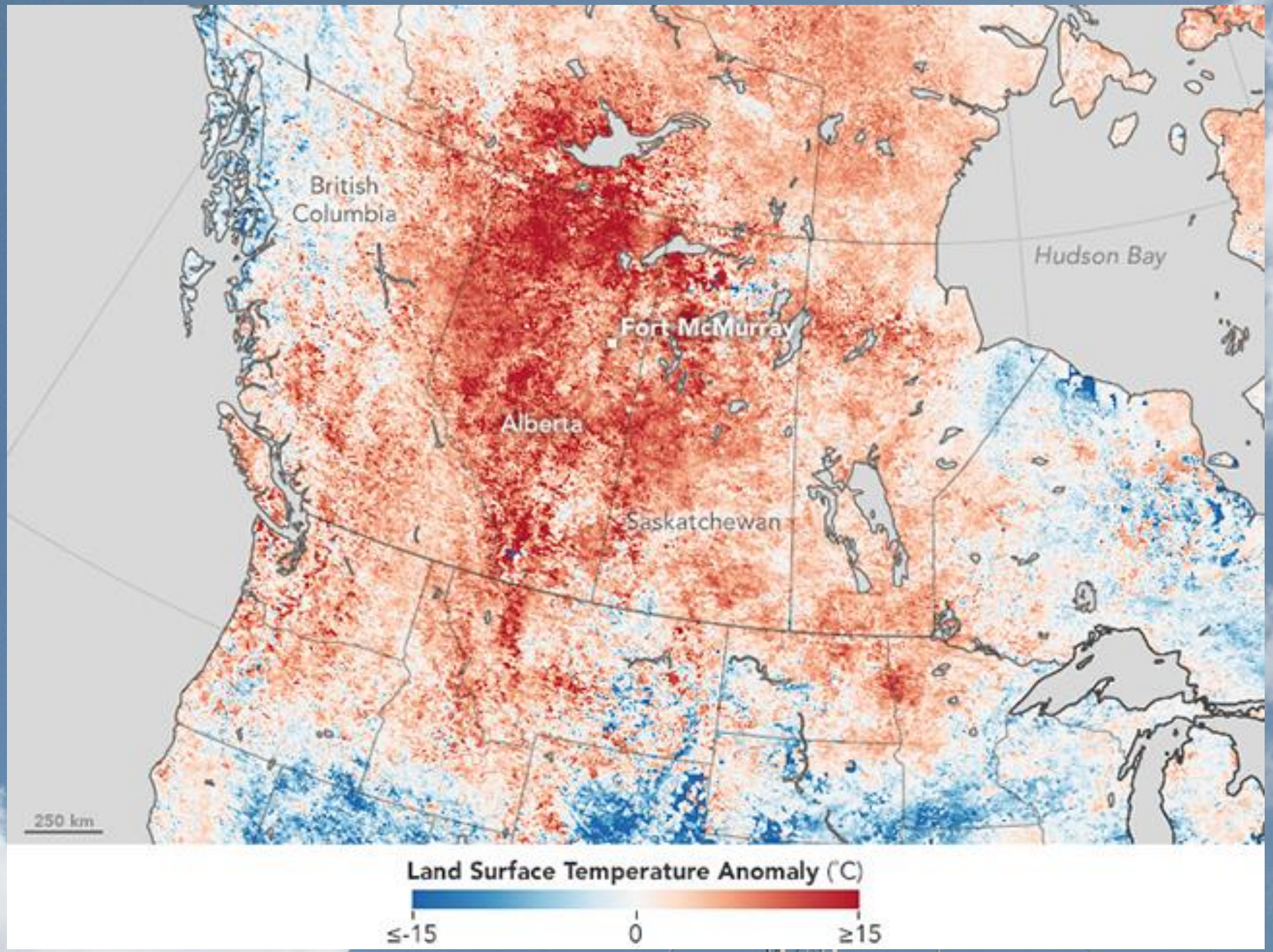
April 17, 2017



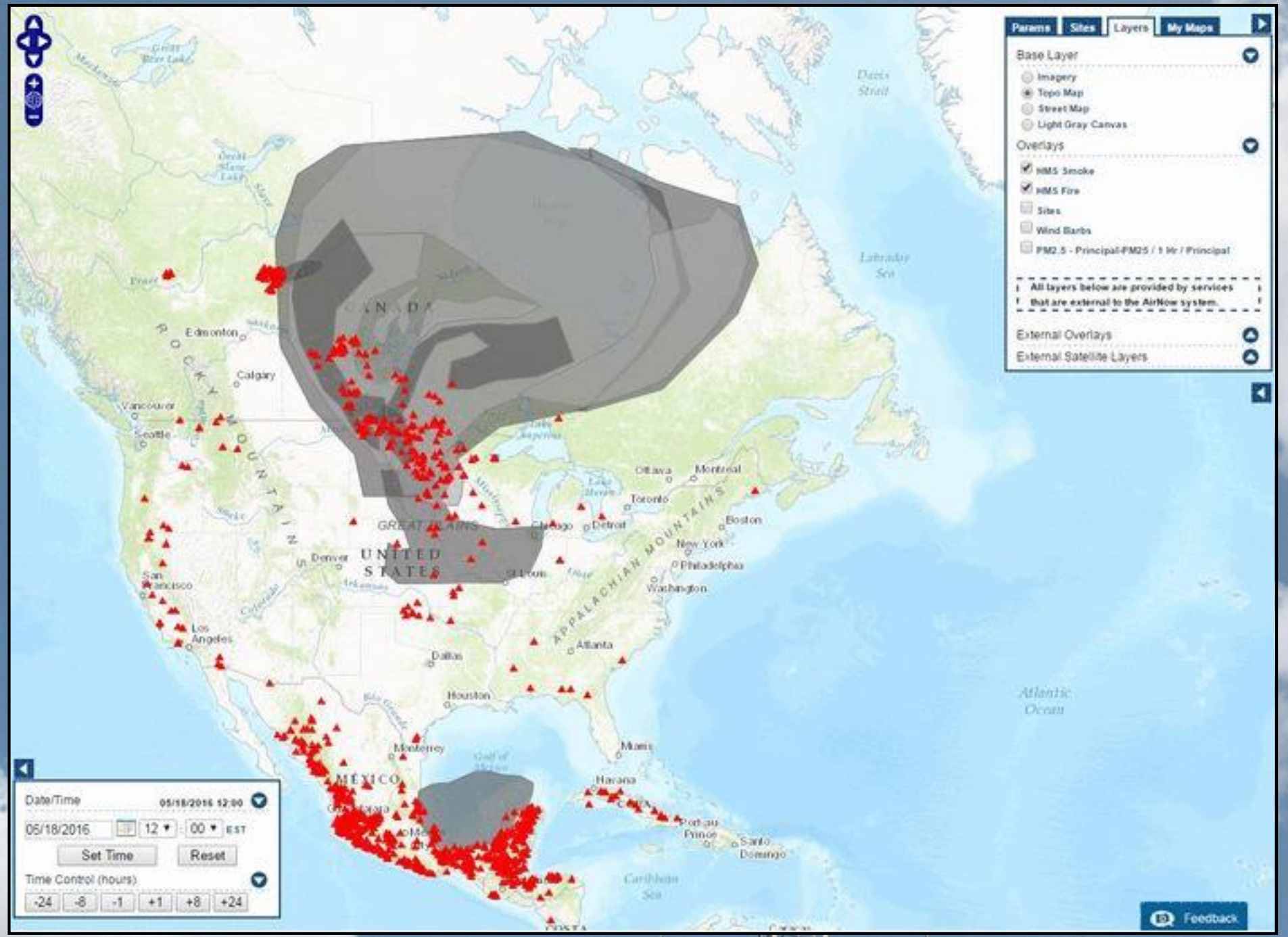
East Providence Top 8-hr			Year	4th Highest		Design Value 2014-2016 (ppb)		
7/22/2016	0.082		2014	0.064				
5/26/2016	0.078		2015	0.071		0.068	Current	
7/6/2016	0.073		2016	0.071		**0.066**	Remove May 25-26	
5/25/2016	**0.071**	4th Highest	2016 (EE)	0.064				
7/21/2016	0.067					2017 Critical Value		
4/22/2016	**0.064**	4th Highest removing				Current		0.071
		May 25-26				Remove May 25-26		0.078
West Greenwich Top 8-hr			Year	4th Highest		Design Value 2014-2016 (ppb)		
5/26/2016	0.084		2014	0.067				
7/22/2016	0.08		2015	0.07		0.070	Current	
5/25/2016	0.078		2016	0.075		**0.069**	Remove May 25-26	
6/7/2016	**0.075**	4th Highest	2016 (EE)	0.07				
7/6/2016	0.075					2017 Critical Value		
9/14/2016	**0.070**	4th Highest removing				Current		0.068
		May 25-26				Remove May 25-26		0.075
Narragansett Top 8-hr			Year	4th Highest		Design Value 2014-2016 (ppb)		
5/25/2016	0.086		2014	0.063				
5/26/2016	0.081		2015	0.077		0.070	Current	
7/6/2016	0.072		2016	0.071		**0.068**	Remove May 25-26	
7/15/2016	**0.071**	4th Highest	2016 (EE)	0.066				
7/16/2016	0.067					2017 Critical Value		
8/24/2016	**0.066**	4th Highest removing				Current		0.065
		May 25-26				Remove May 25-26		0.070



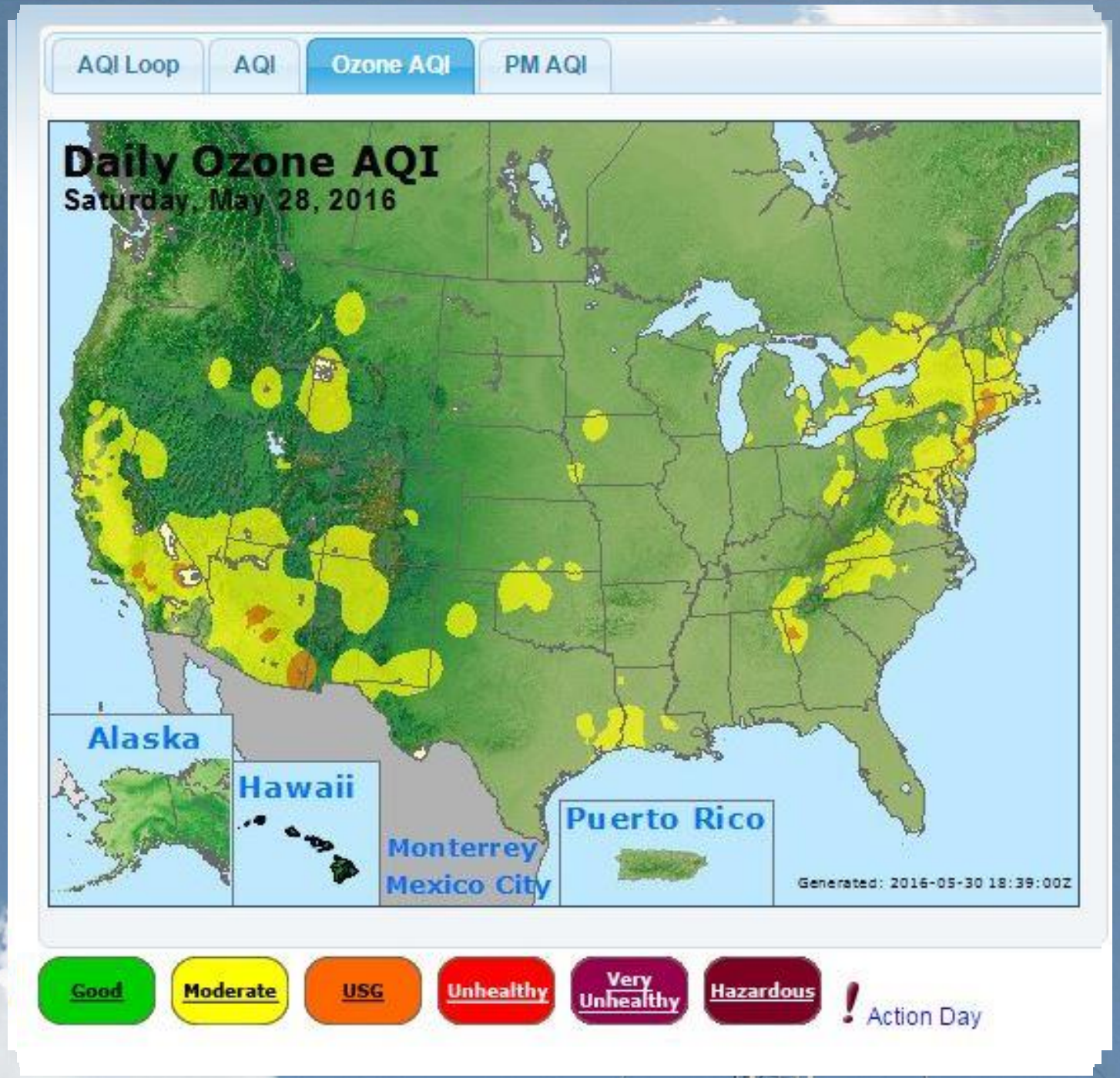
A persistent area of high pressure dominated the Midwest 5/19-5/23. By 5/24, high pressure and the plume migrated east.



Land surface temperature anomalies from April 26 through May 3, 2016 over Canada and the northern U.S., relative to the 2000-2010 average. (NASA Earth Observatory)

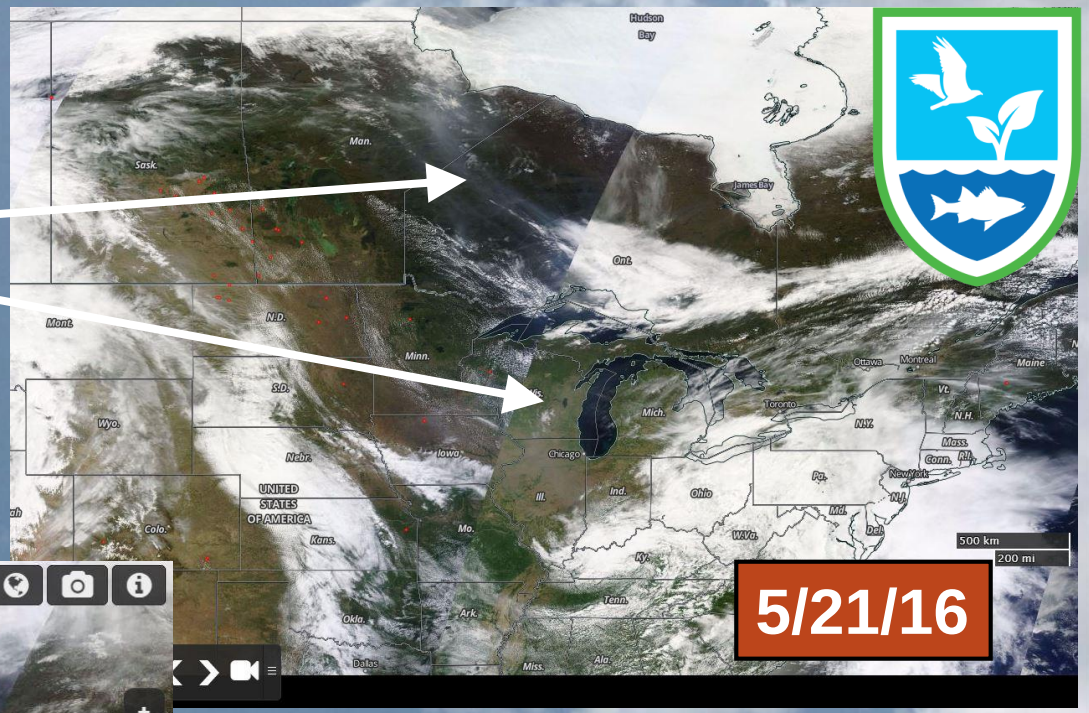


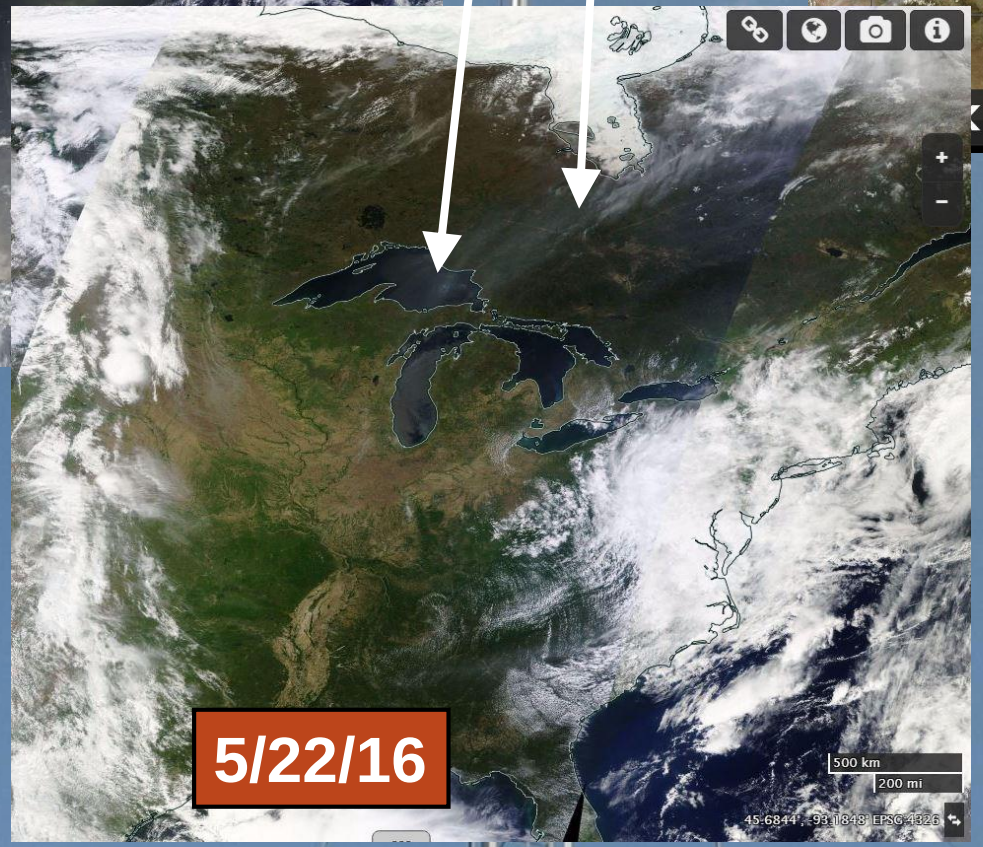
The Hazards Mapping system (HMS) creates a daily fire smoke analysis for the US and Canada using sensors and environmental satellite data. Note vast areas of smoke from Ft. McMurray represented by shades of gray. Fire hot spots are indicated in red.

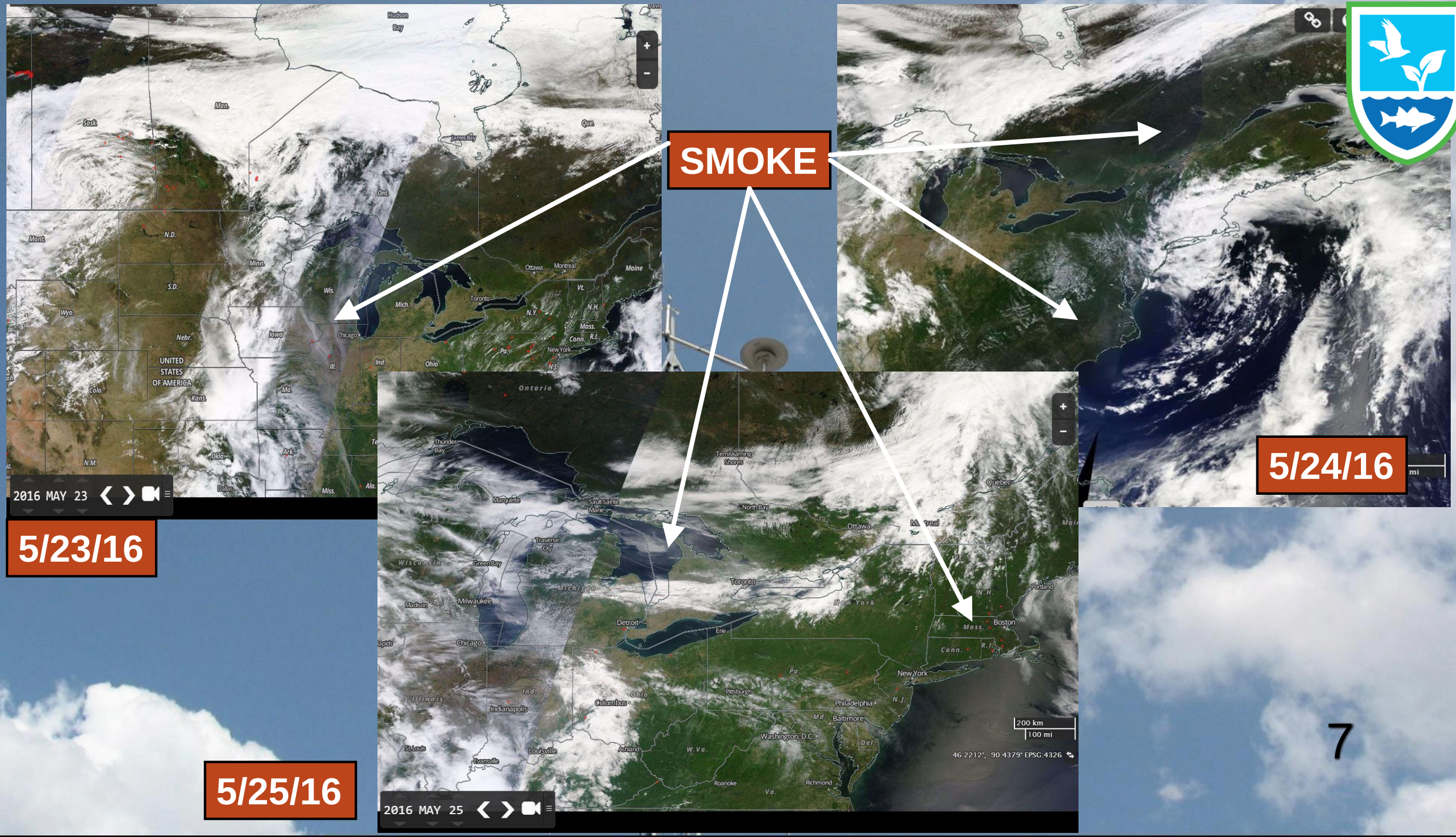


Plume tracks from Upper Midwest through the Great Lake region into the Northeast peaking on 5/2516 and 5/26/2016

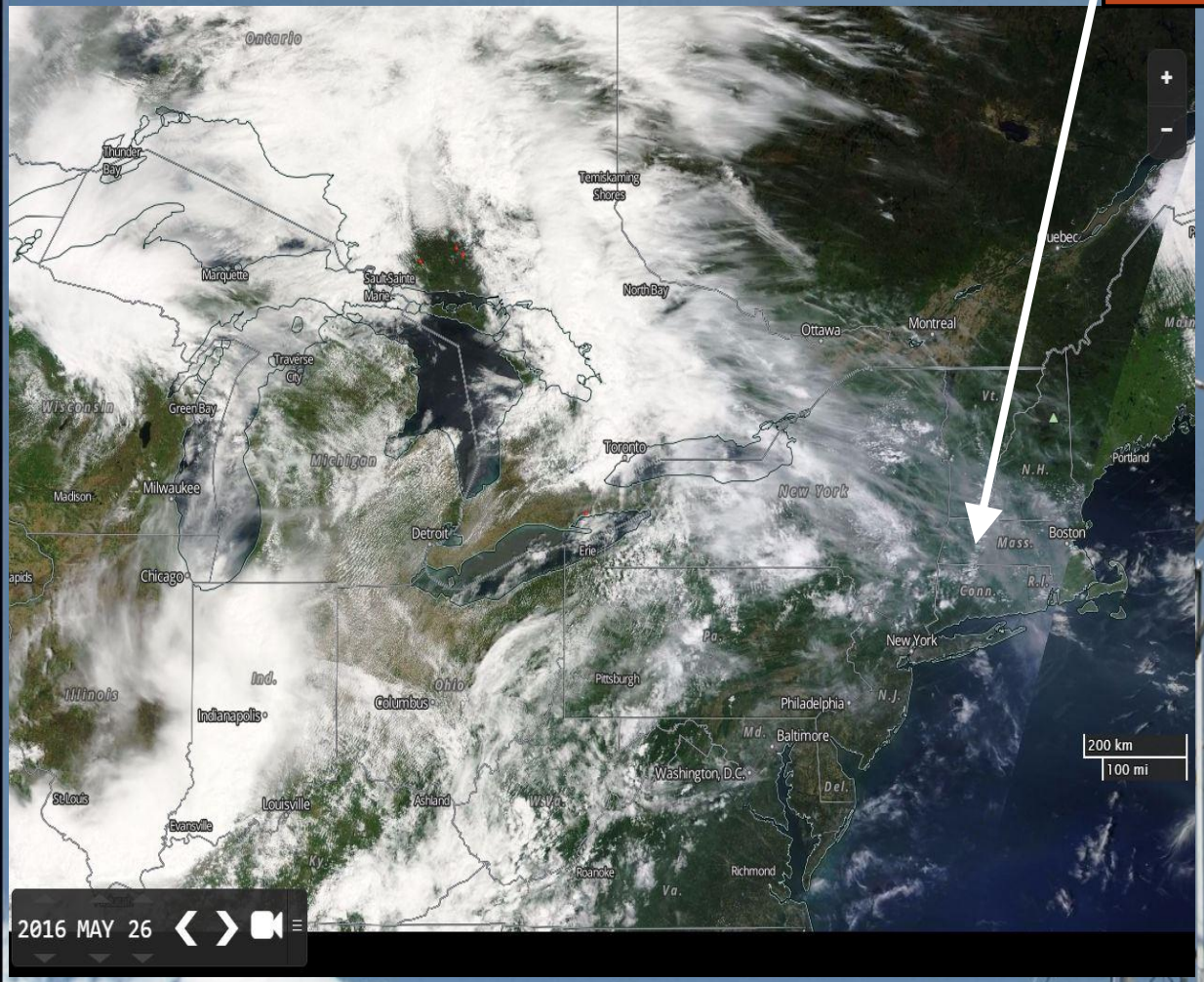
SMOKE



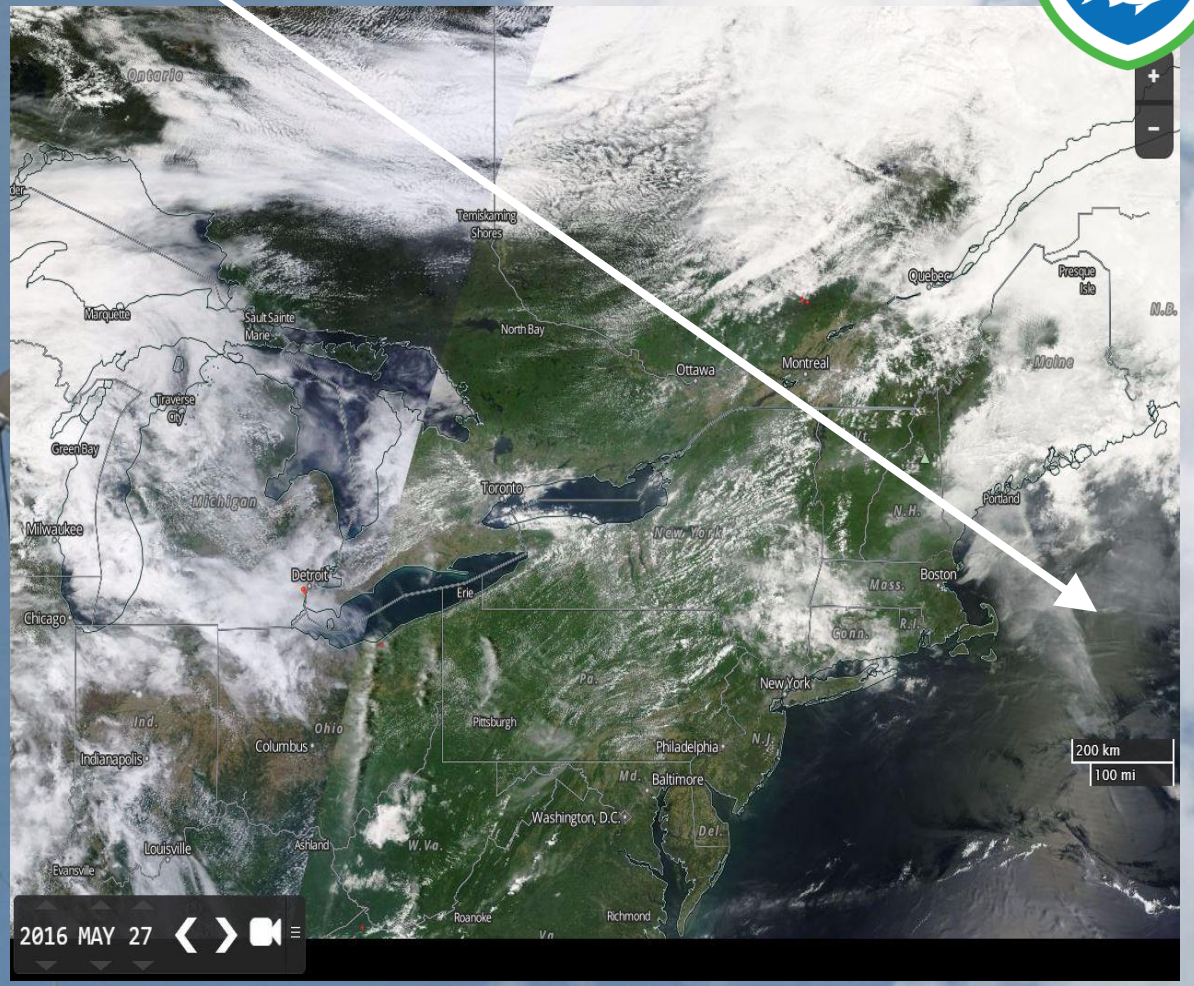



SMOKE
5/23/16
5/24/16
5/25/16
2016 MAY 23
2016 MAY 25
UNITED STATES OF AMERICA
Hudson Bay
James Bay
Ontario
Quebec
Wisconsin
Michigan
New York
Illinois
Ohio
Chicago
Toronto
Ottawa
Montreal
Boston
New York
Detroit
Milwaukee
Indianapolis
Columbus
Philadelphia
Baltimore
Washington, D.C.
200 km
100 mi
46.2212°, -90.4379° EPSG:4326

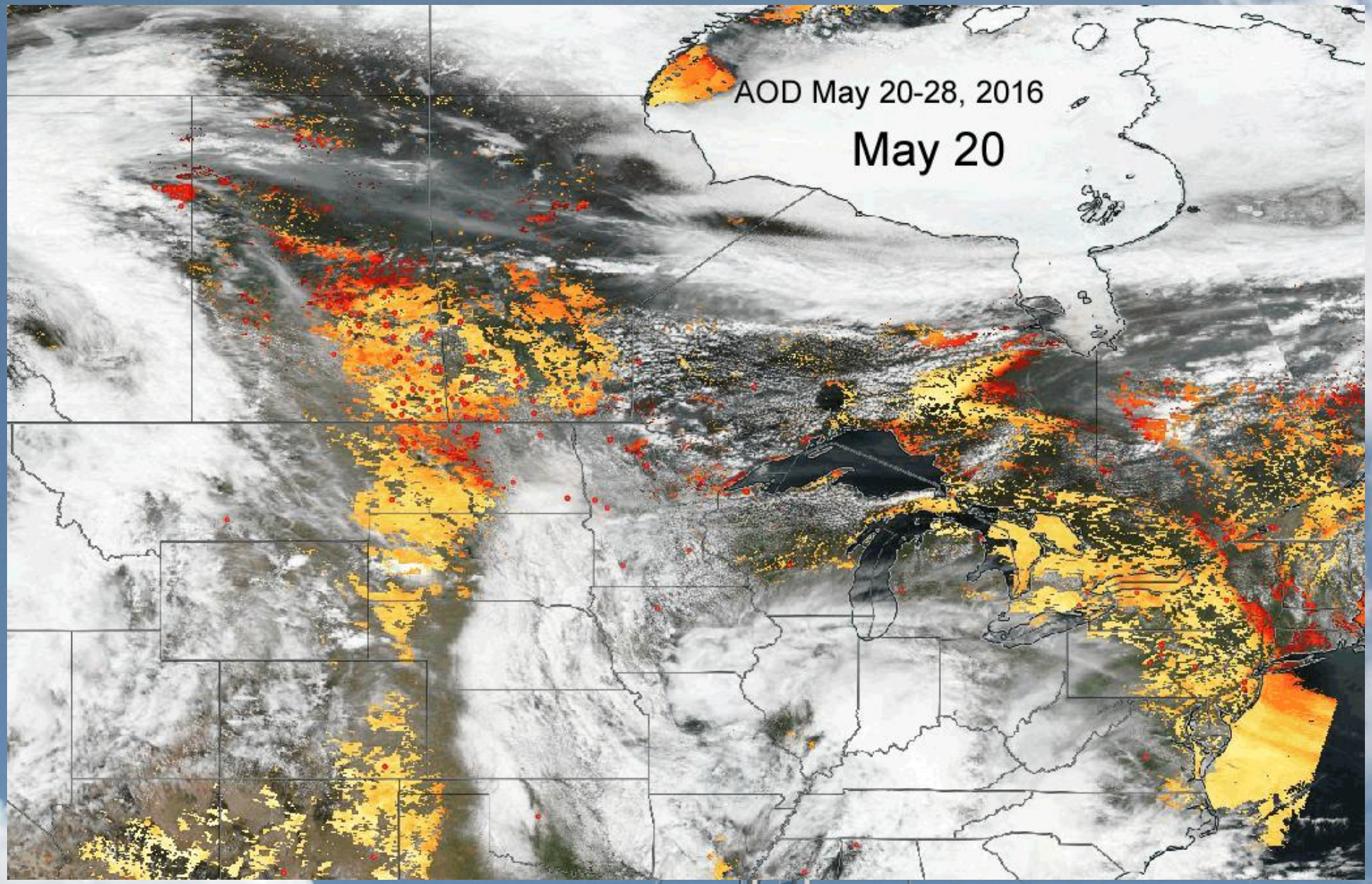
SMOKE



5/26/16



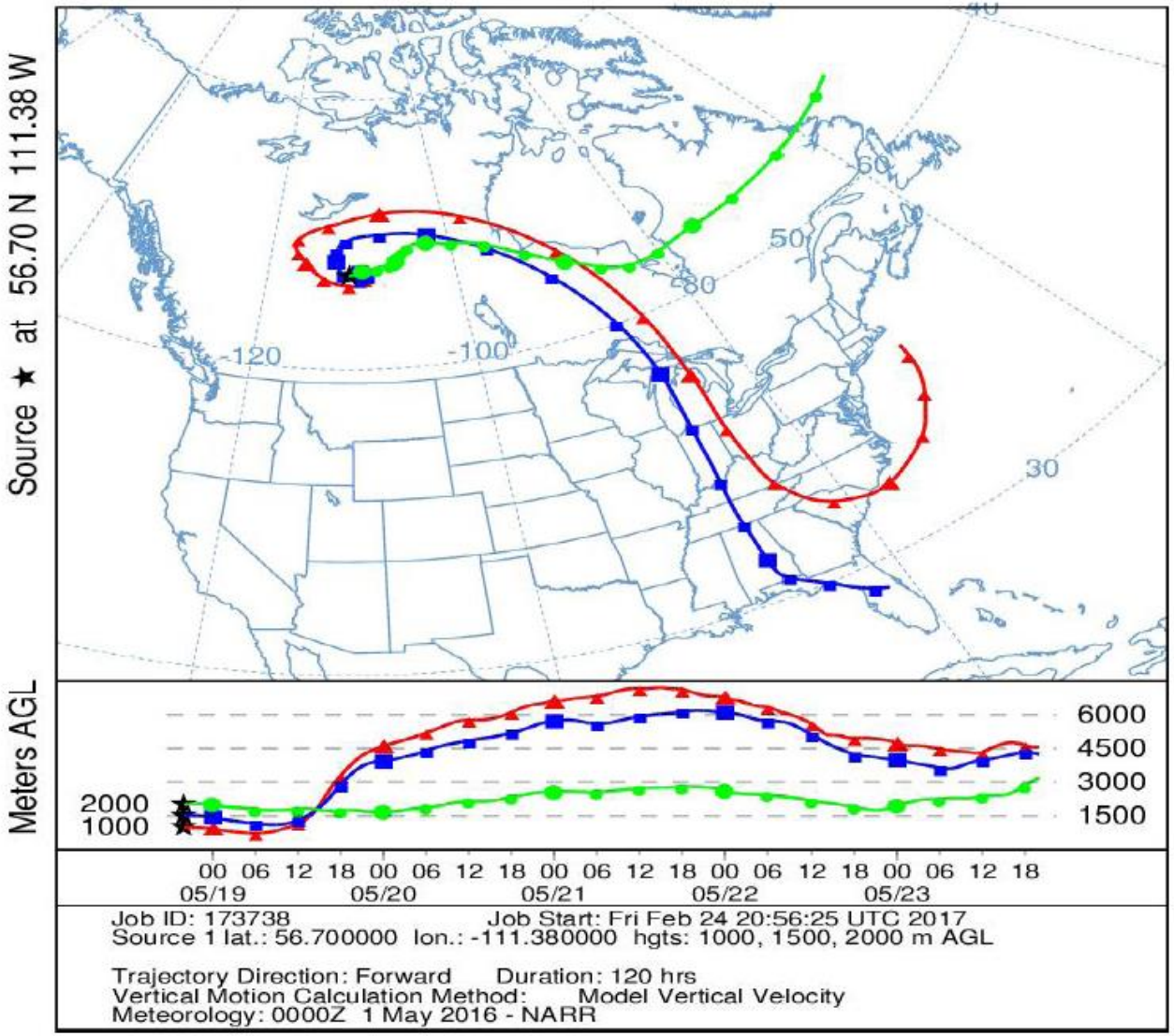
5/27/16



Warmer colors indicate higher AOD (aerosol optical depths) and higher column aerosol concentrations. Lobe of plume grazes RI on 5/20. Brunt of smoke plume arrives early 5/25.

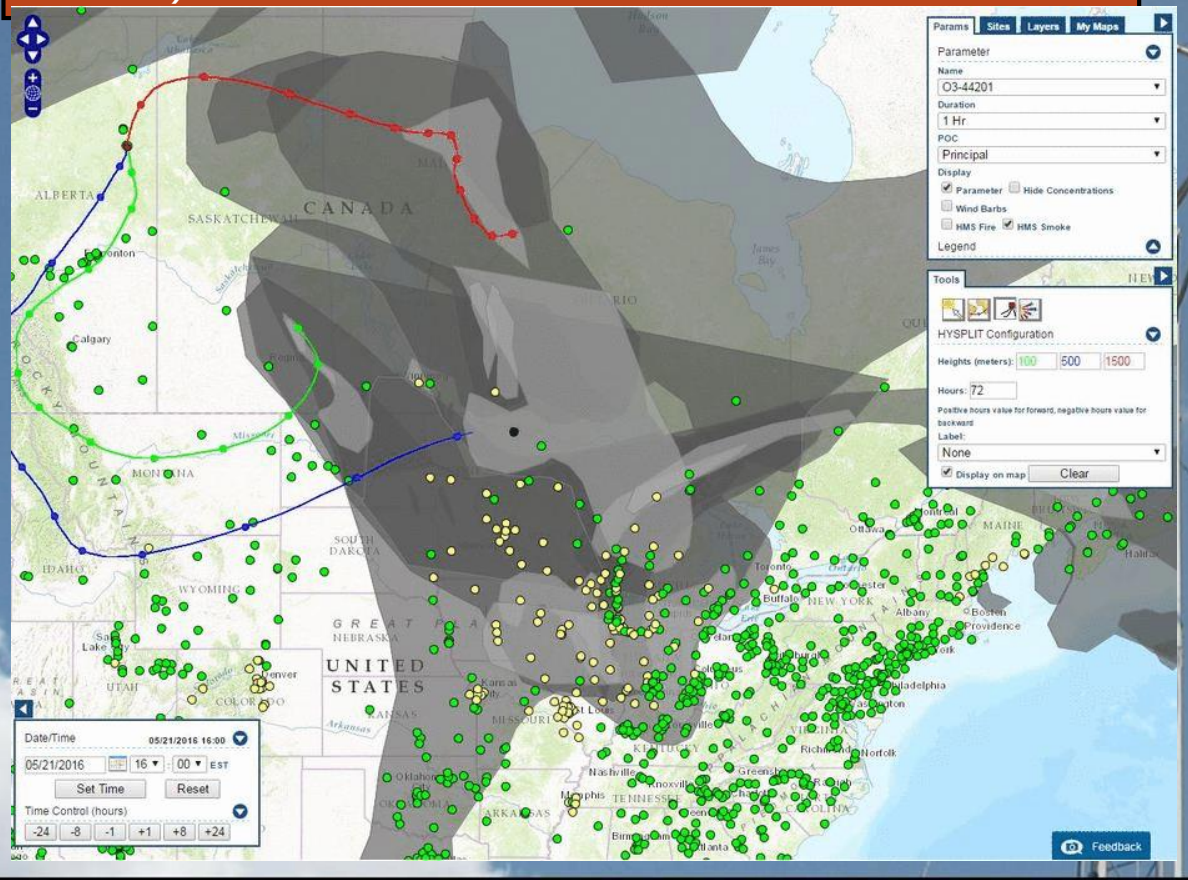
NOAA HYSPLIT Model

120-hr Forward Trajectories Starting at 2000 UTC May 18, 2016

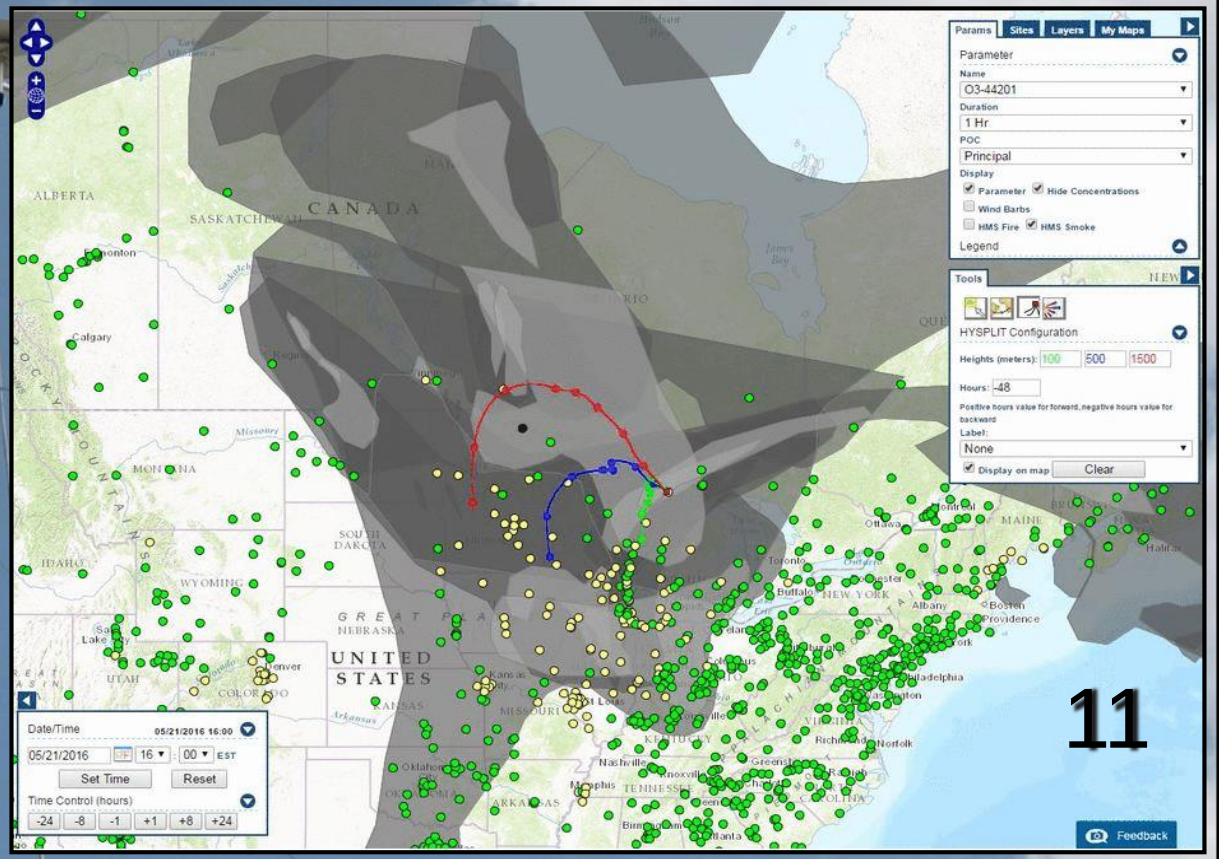


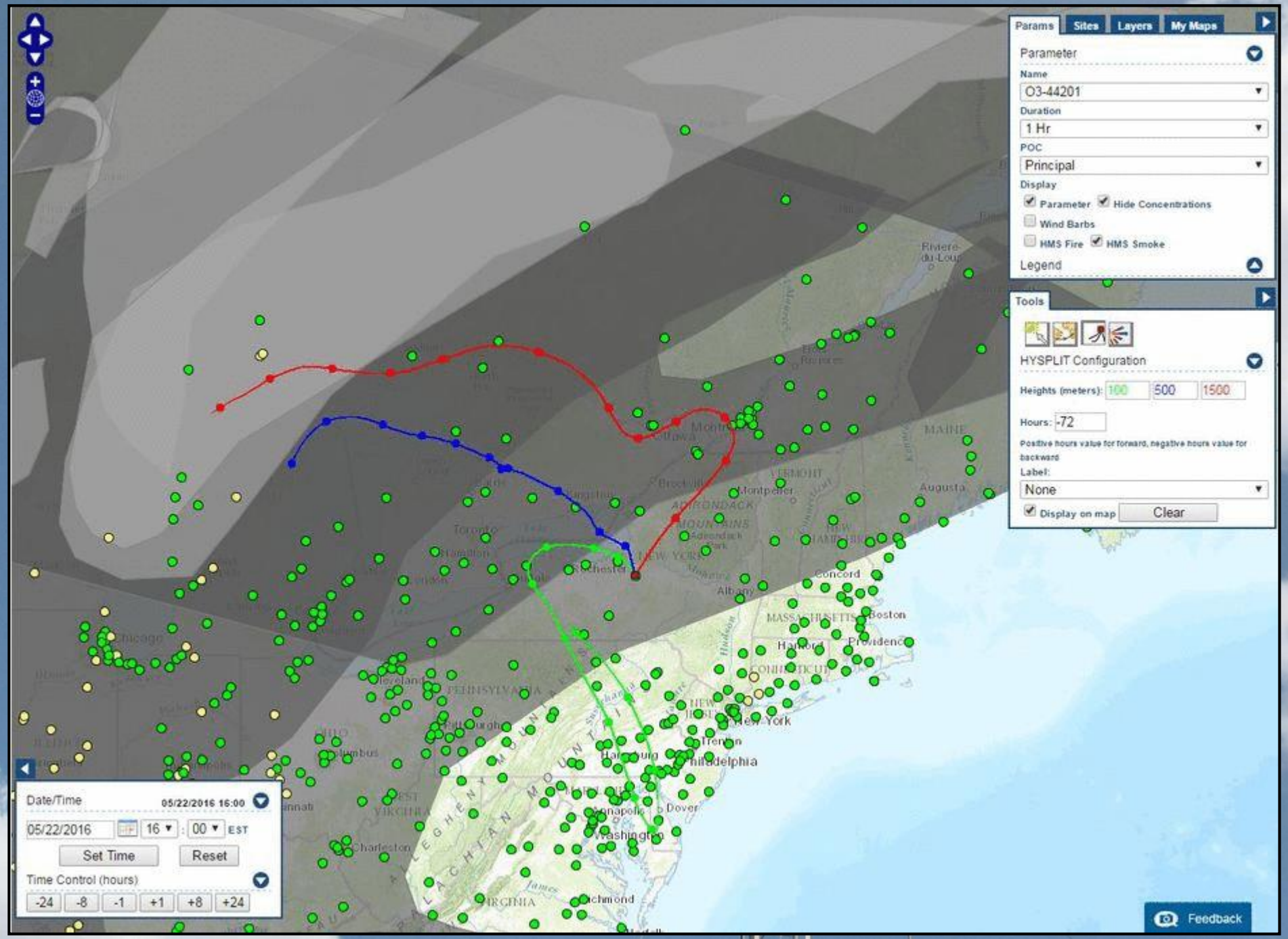
120 hr Trajectory Analysis at heights of 1000, 1500, and 2000 meters. Red (1000m) and blue (1500m) lines indicate path from Fort McMurray into the Great Lakes Region on May 21st (indicated by larger marker), where the plume became trapped under stagnant high pressure.

72 hour HYSPLIT forward trajectory analysis for May 21 and May 22 from Fort McMurray. The smoke plume is well established over the Upper Midwest and Great Lakes and north, with trajectories leading back to Fort McMurray (dark red dot).

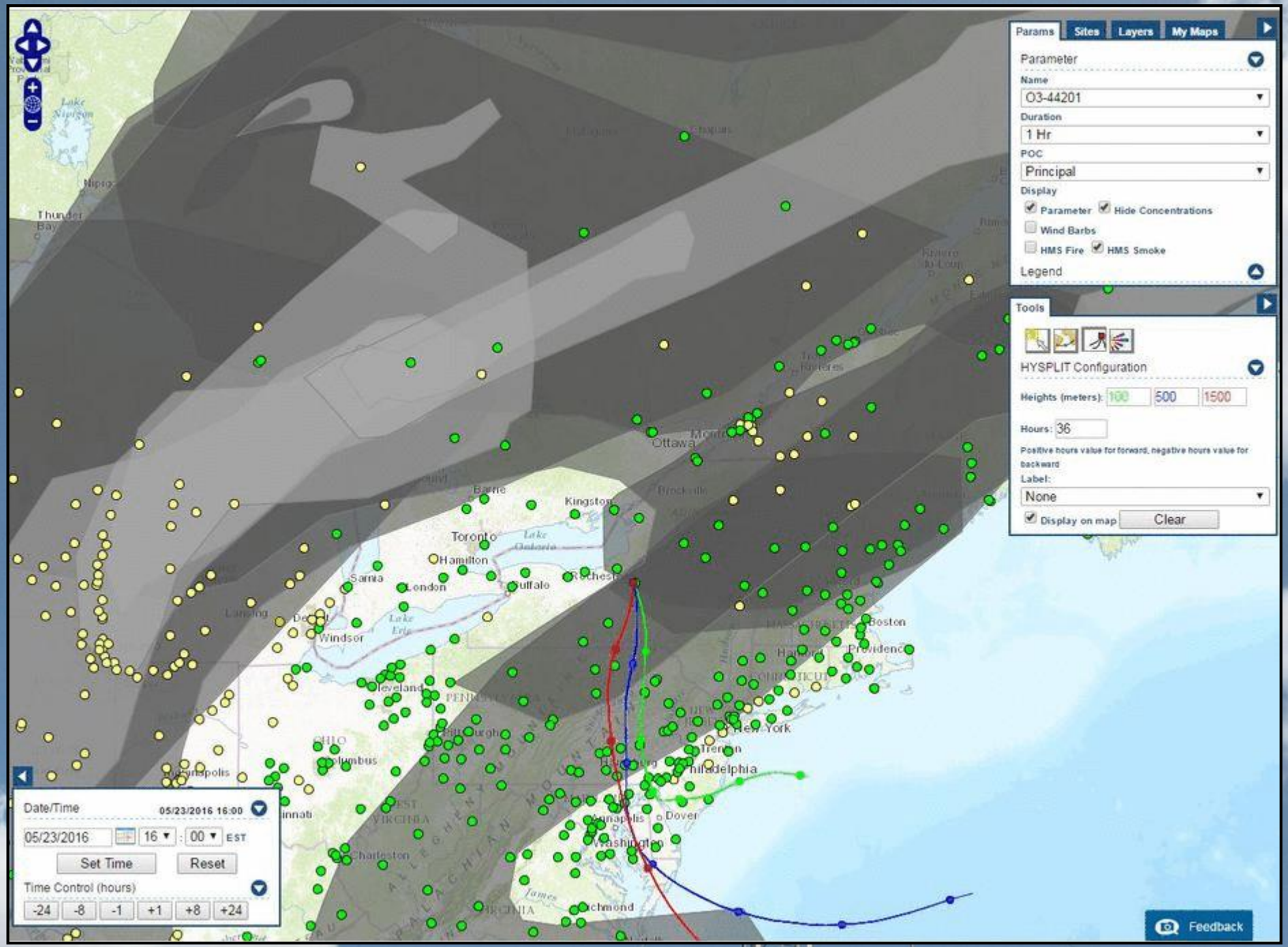


72 hour HYSPLIT backward and forward trajectory analysis for May 21-23 for Seney, MI (dark red dot). Short backward trajectories show stagnation for May 21. May 22 shows some movement east with more pronounced forward progress on May 23 to the east shown by forward trajectory.

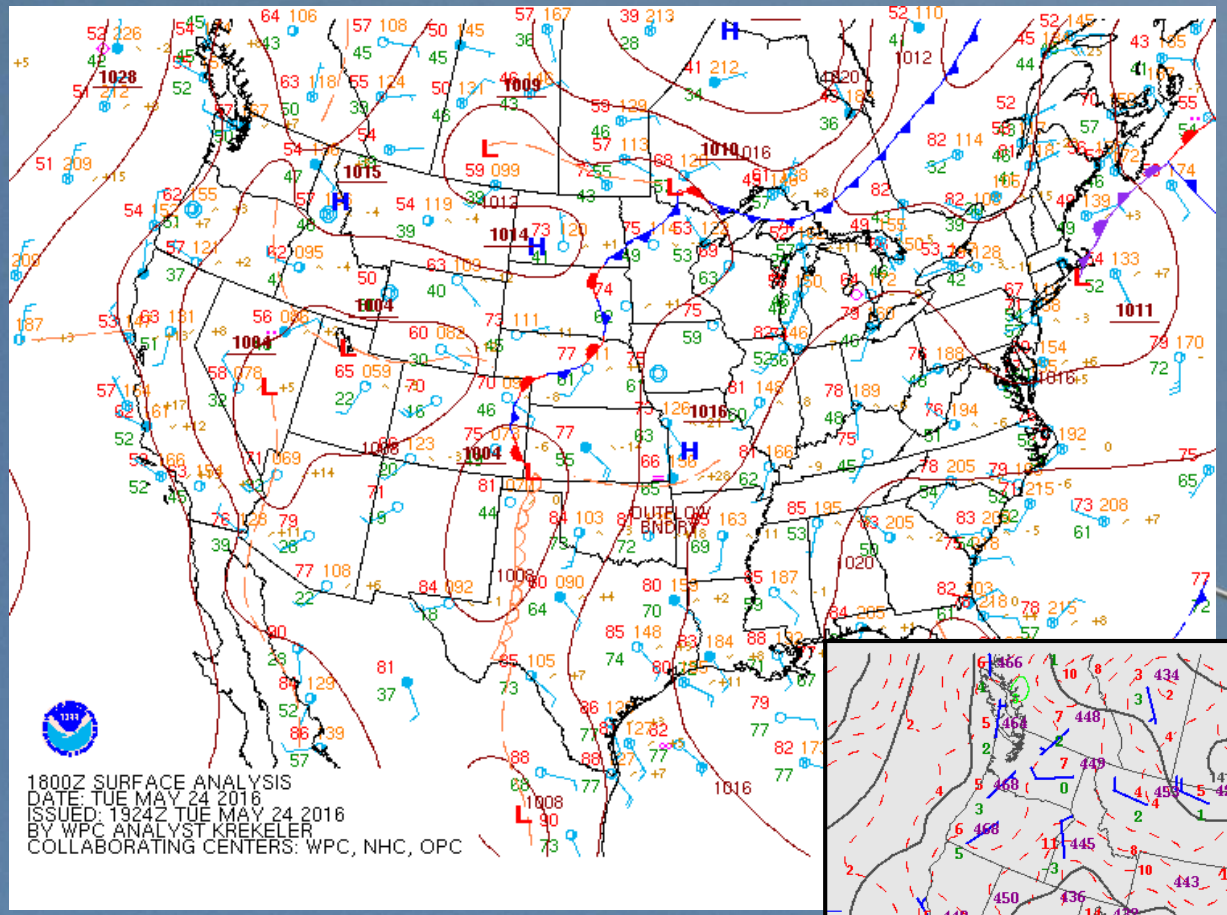


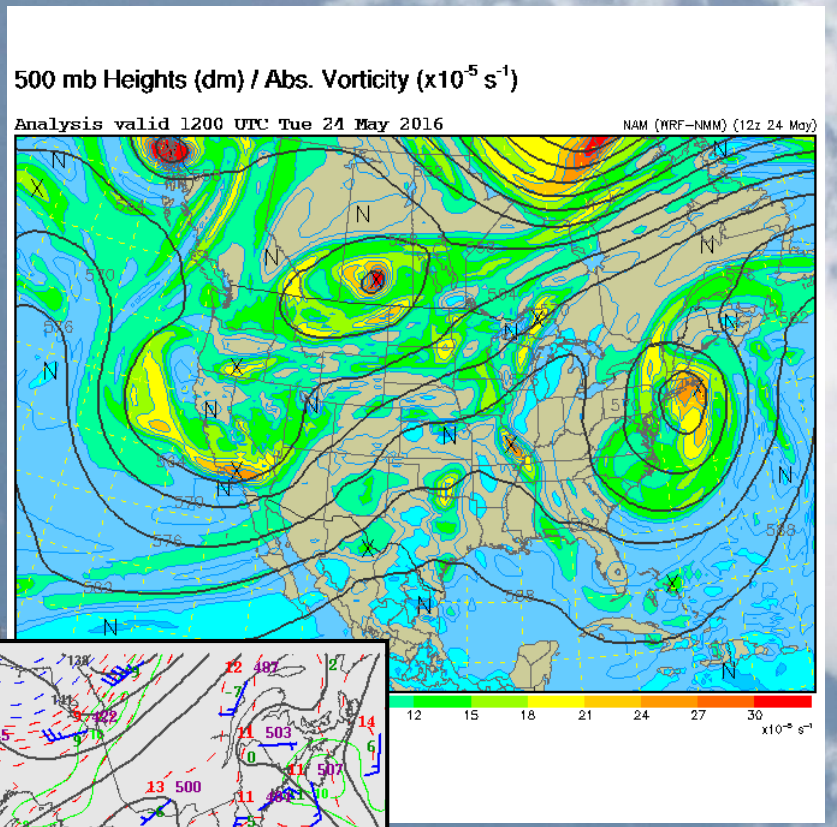


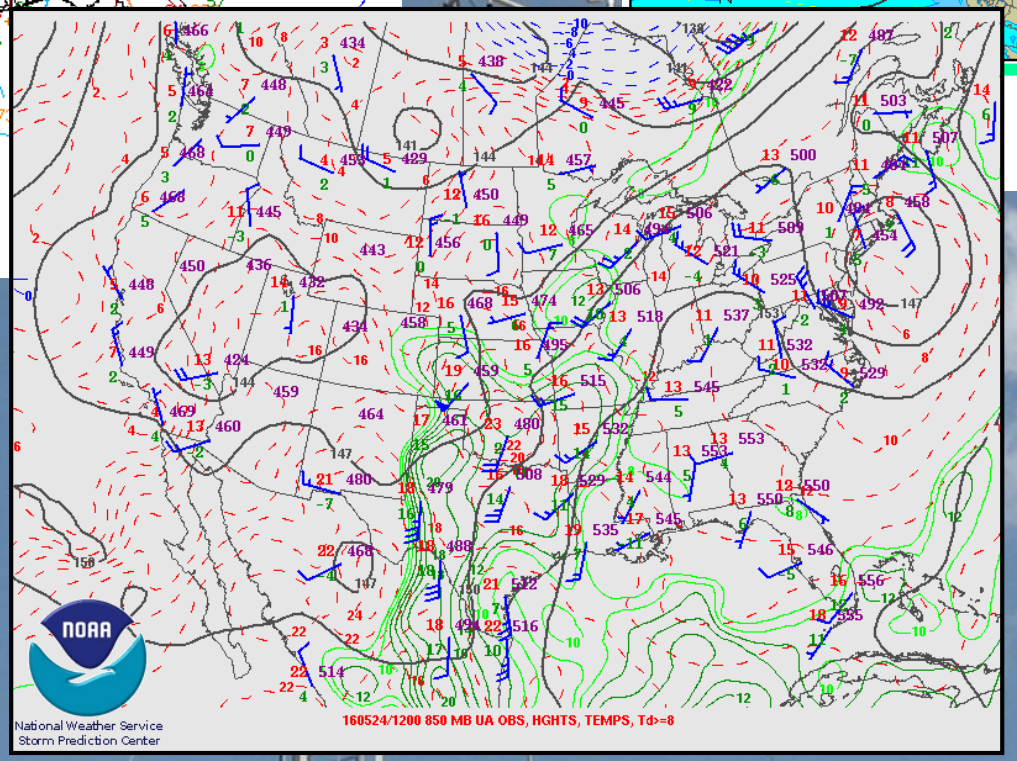
72 hour HYSPLIT backward trajectory analysis for East Syracuse for May 22nd show the air mass has traveled at 500 and 1500 m from a smoke rich location just north of Michigan, with a more northerly path on May 23rd.



72 hour HYSPLIT forward trajectory analysis for East Syracuse for May 23rd show northerly flow, turning more northwest on May 24th. By May 25th, northwest flows have transported plume to Rhode Island.


1800Z SURFACE ANALYSIS
DATE: TUE MAY 24 2016
ISSUED: 1924Z TUE MAY 24 2016
BY WPC ANALYST KREKELER
COLLABORATING CENTERS: WPC, NHC, OPC

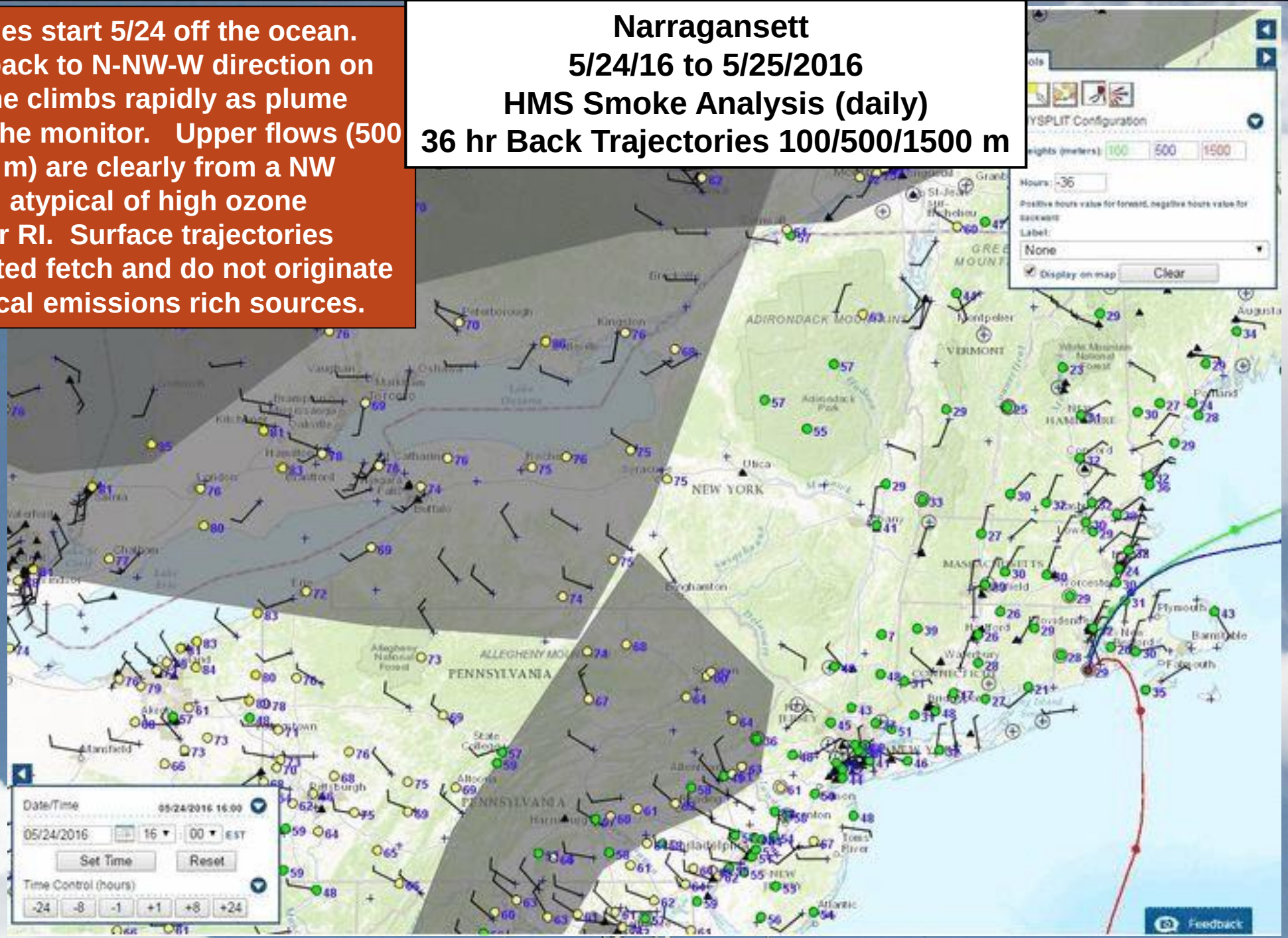

500 mb Heights (dm) / Abs. Vorticity (x10^{-5} s^{-1})
Analysis valid 1200 UTC Tue 24 May 2016
NAM (WRF-NMM) (12z 24 May)
12 15 18 21 24 27 30
x10^{-5} s^{-1}

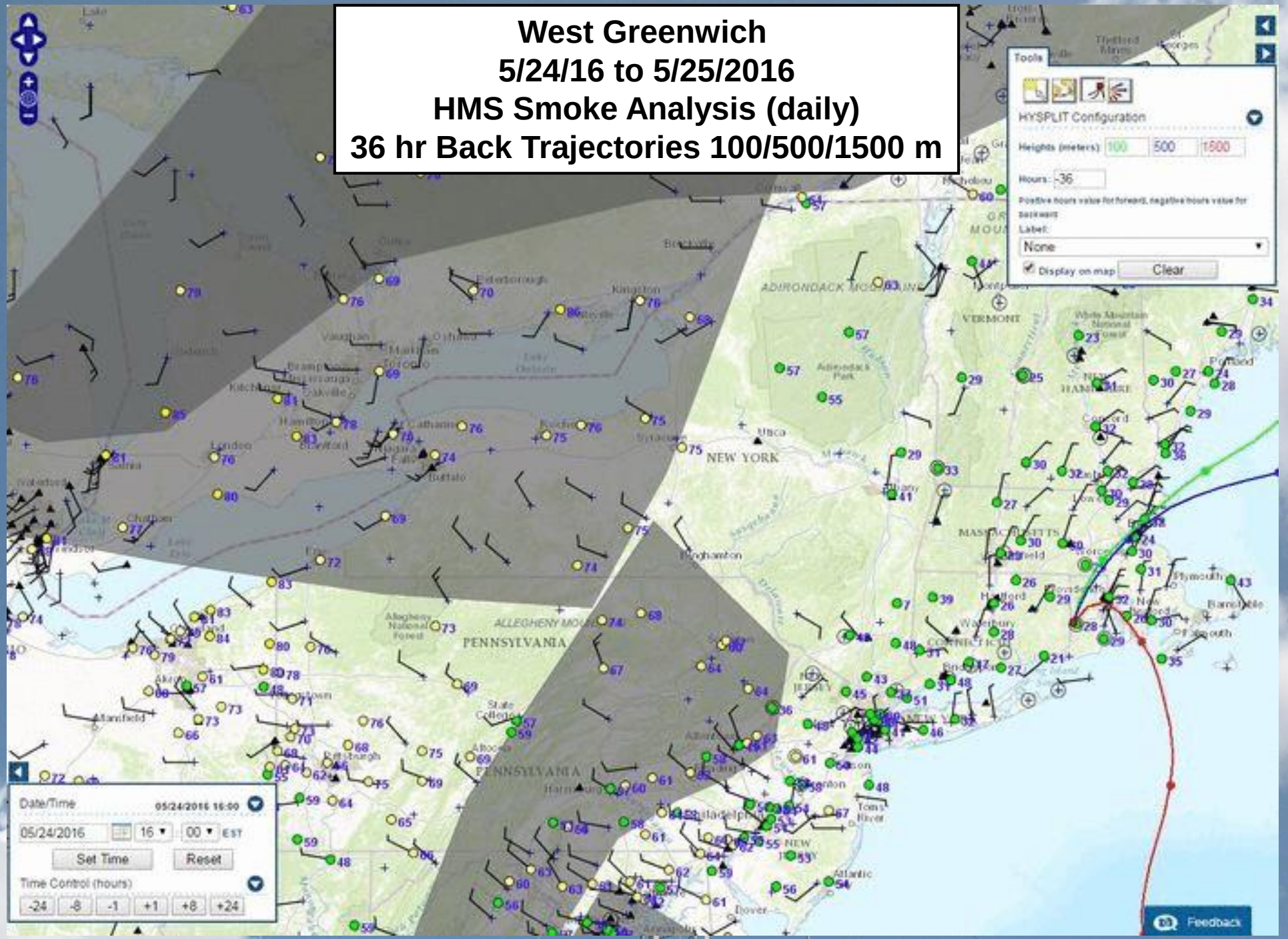

NOAA
National Weather Service
Storm Prediction Center
160524/1200 850 MB UA OBS, HGHTS, TEMPS, Td>=8

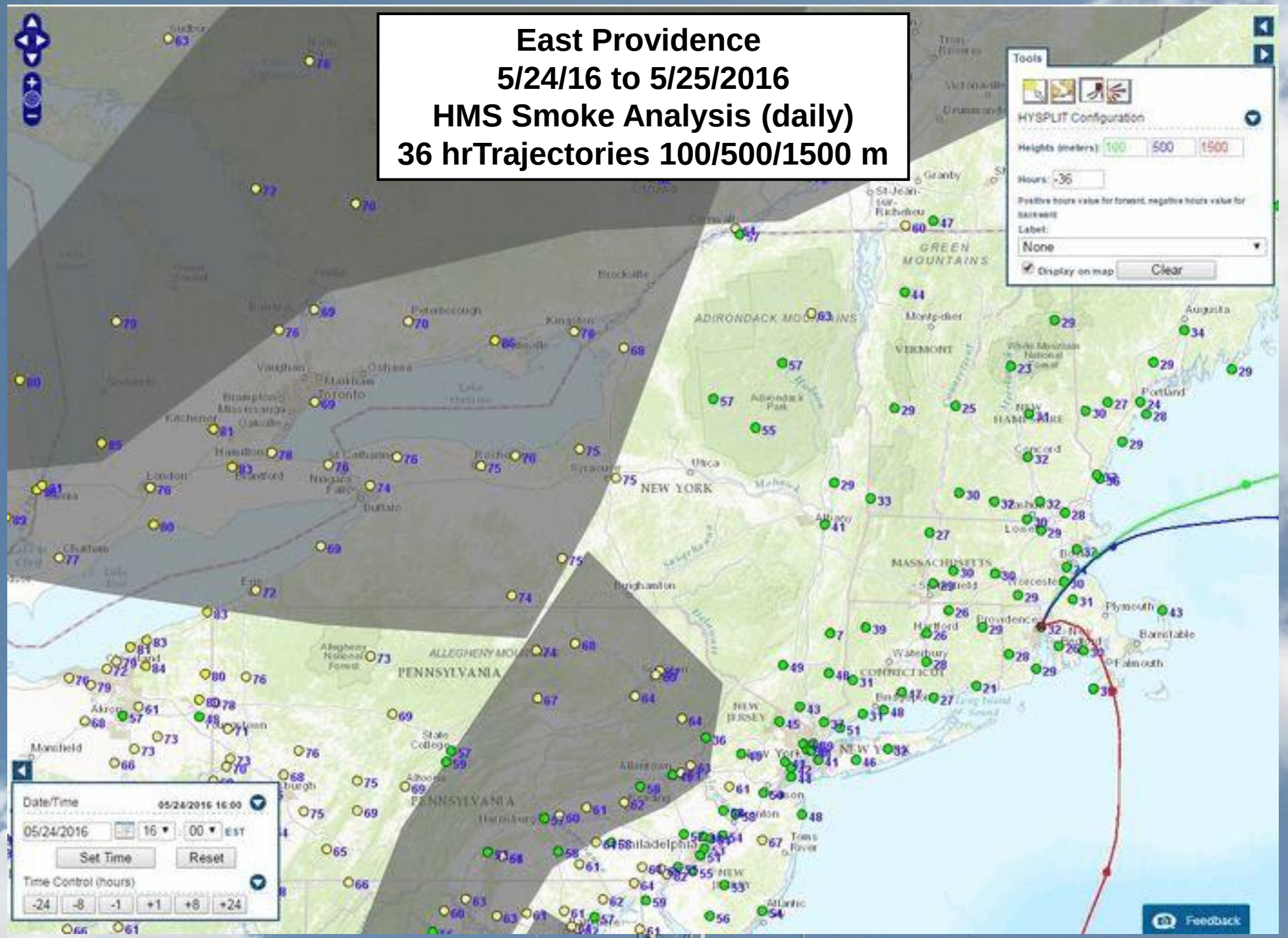
5/24/2016

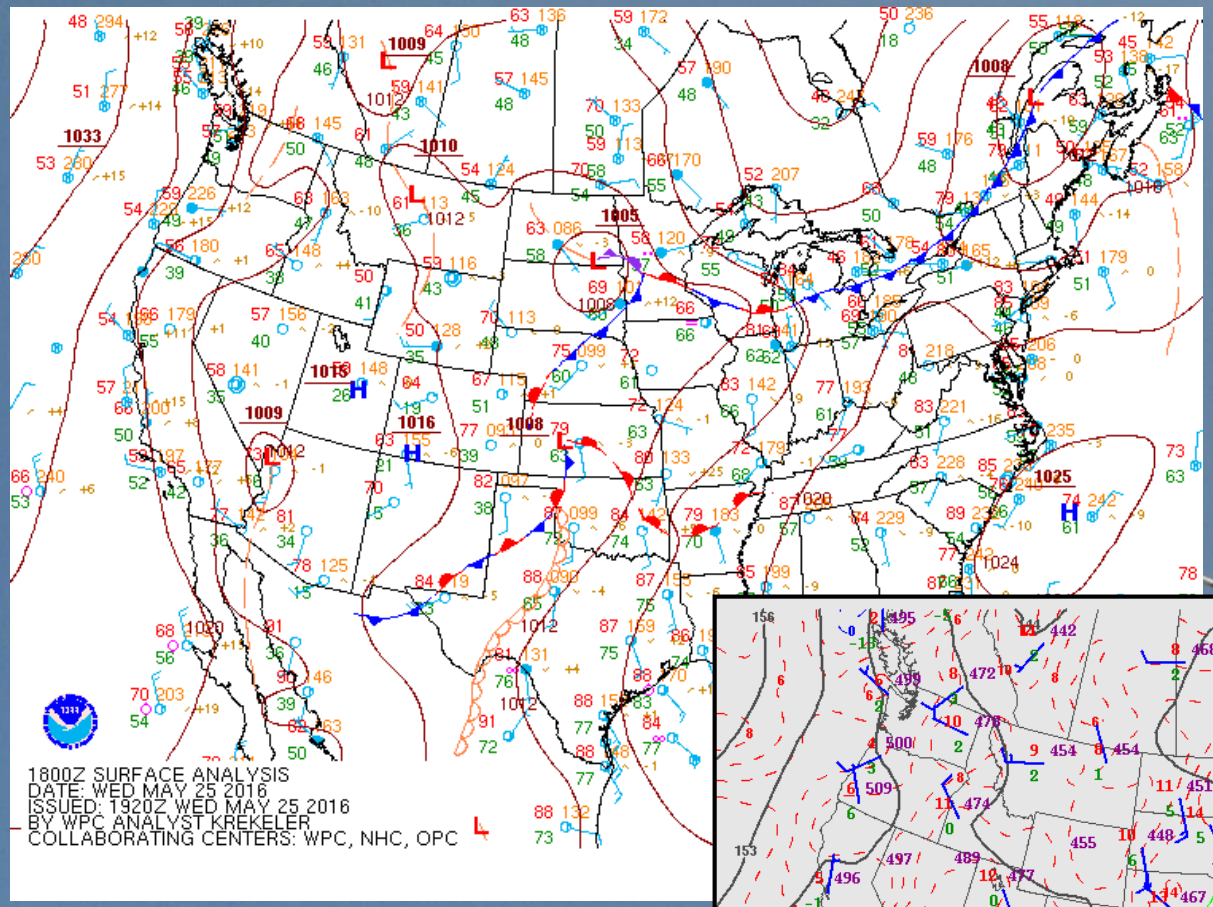
Trajectories start 5/24 off the ocean. As they back to N-NW-W direction on 5/25 ozone climbs rapidly as plume impacts the monitor. Upper flows (500 and 1500 m) are clearly from a NW direction, atypical of high ozone events for RI. Surface trajectories have limited fetch and do not originate from typical emissions rich sources.

Narragansett
5/24/16 to 5/25/2016
HMS Smoke Analysis (daily)
36 hr Back Trajectories 100/500/1500 m




West Greenwich
5/24/16 to 5/25/2016
HMS Smoke Analysis (daily)
36 hr Back Trajectories 100/500/1500 m
Tools
HYSPLIT Configuration
Heights (meters): 100 500 1500
Hours: -36
Label:
None
Display on map
Clear
Date/Time
05/24/2016 16:00
05/24/2016
16
00
EST
Set Time
Reset
Time Control (hours)
-24
-8
-1
+1
+8
+24
NEW YORK
PENNSYLVANIA
VERMONT
MASSACHUSETTS
Feedback


East Providence
5/24/16 to 5/25/2016
HMS Smoke Analysis (daily)
36 hrTrajectories 100/500/1500 m
Tools
HYSPLIT Configuration
Heights (meters): 100 500 1500
Hours: -36
Label:
None
Display on map
Clear
Date/Time
05/24/2016
Set Time
Reset
Time Control (hours)
-24 -8 -1 +1 +8 +24
Feedback


1800Z SURFACE ANALYSIS
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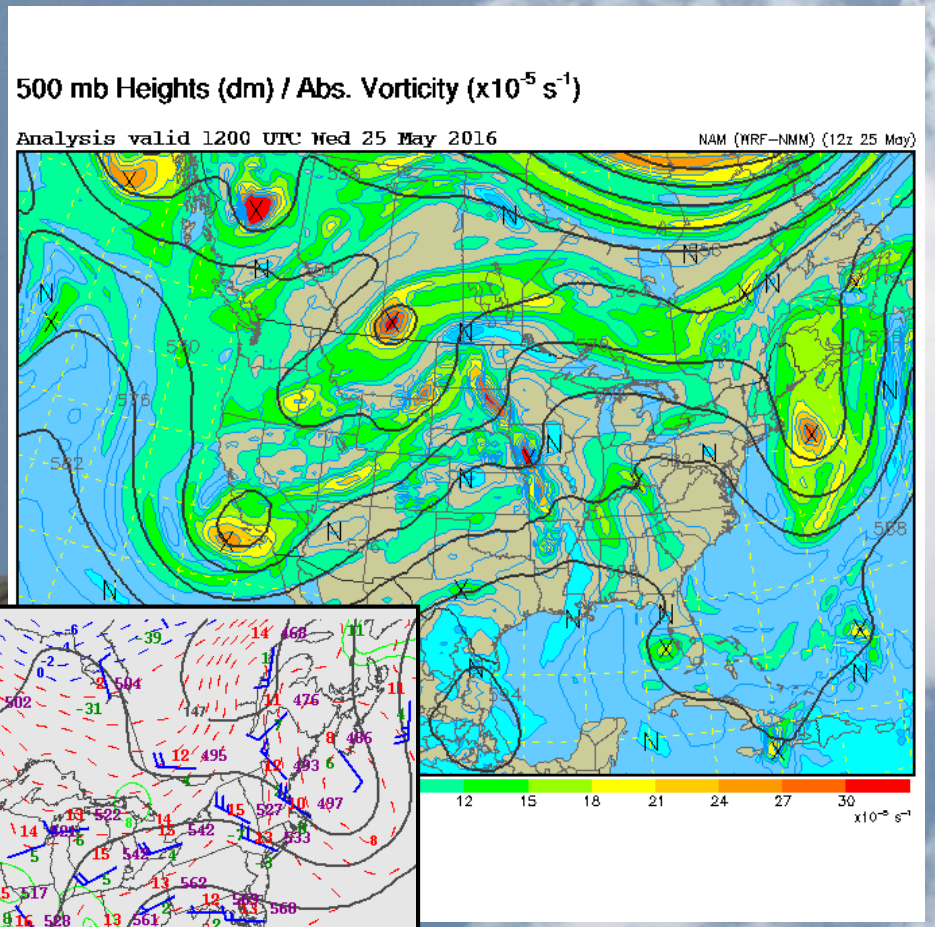
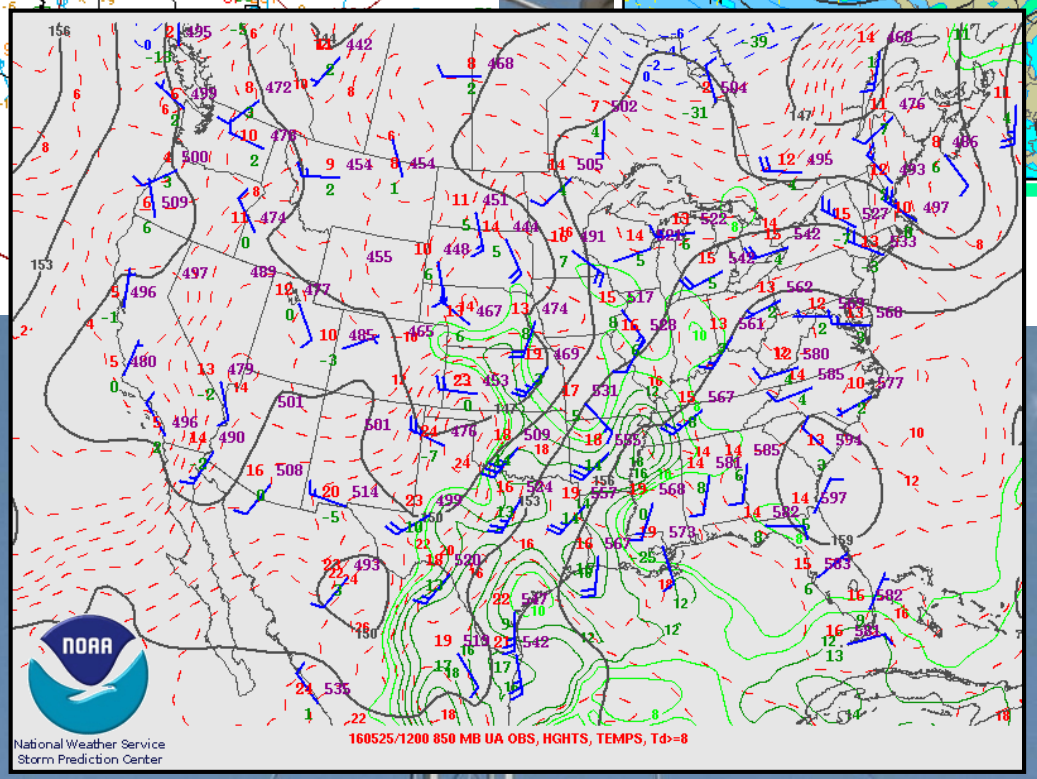
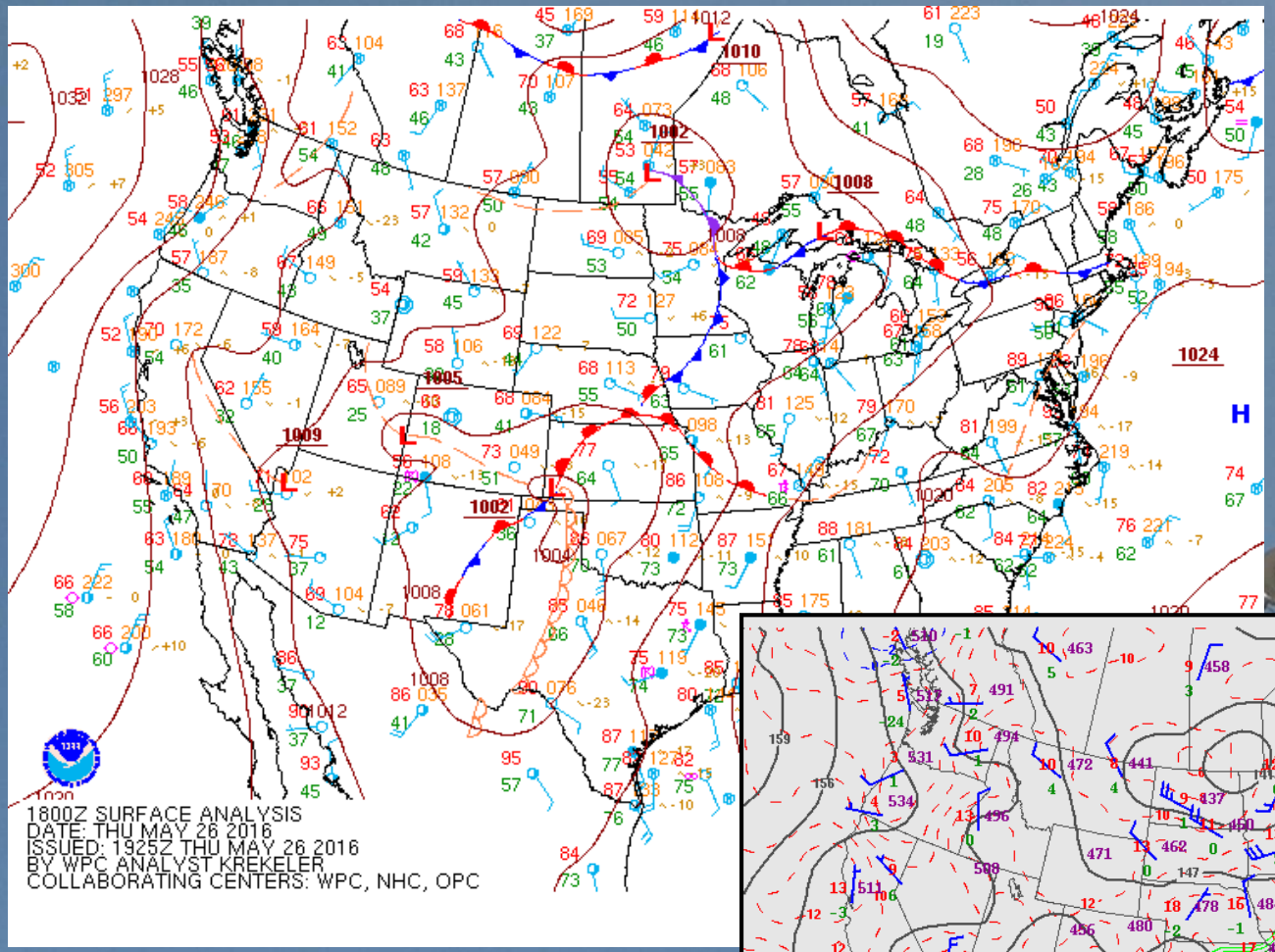
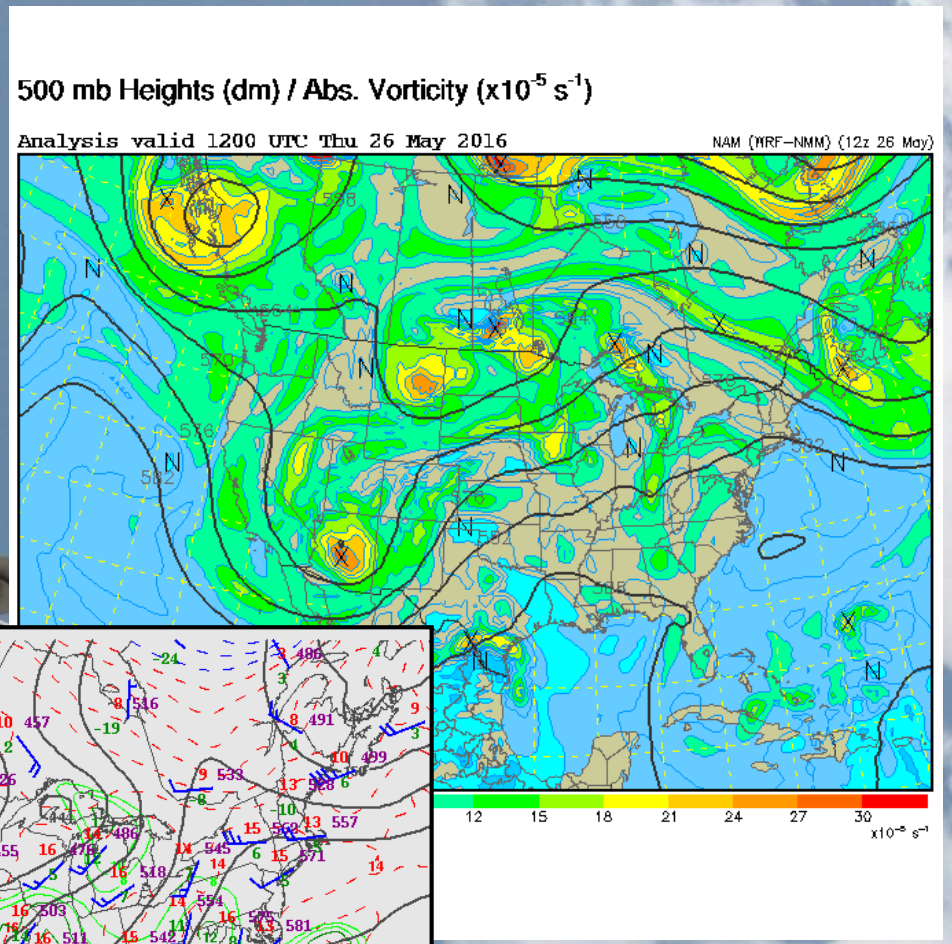
ISSUED: 1920Z WED MAY 25 2016
BY WPC ANALYST KREKELER
COLLABORATING CENTERS: WPC, NHC, OPC

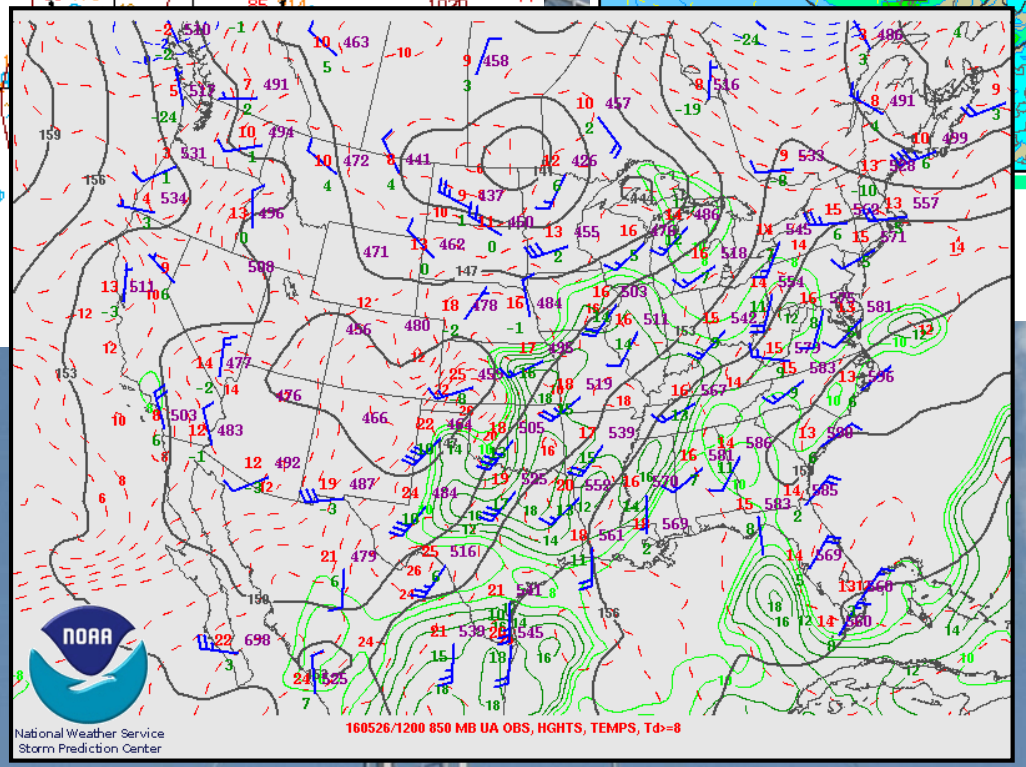

500 mb Heights (dm) / Abs. Vorticity (x10^{-5} s^{-1})
Analysis valid 1200 UTC Wed 25 May 2016
NAM (WRF-NMM) (12z 25 May)
12 15 18 21 24 27 30
x10^{-5} s^{-1}


NOAA
National Weather Service
Storm Prediction Center
160525/1200 850 MB UA OBS, HGHTS, TEMPS, Td>=8

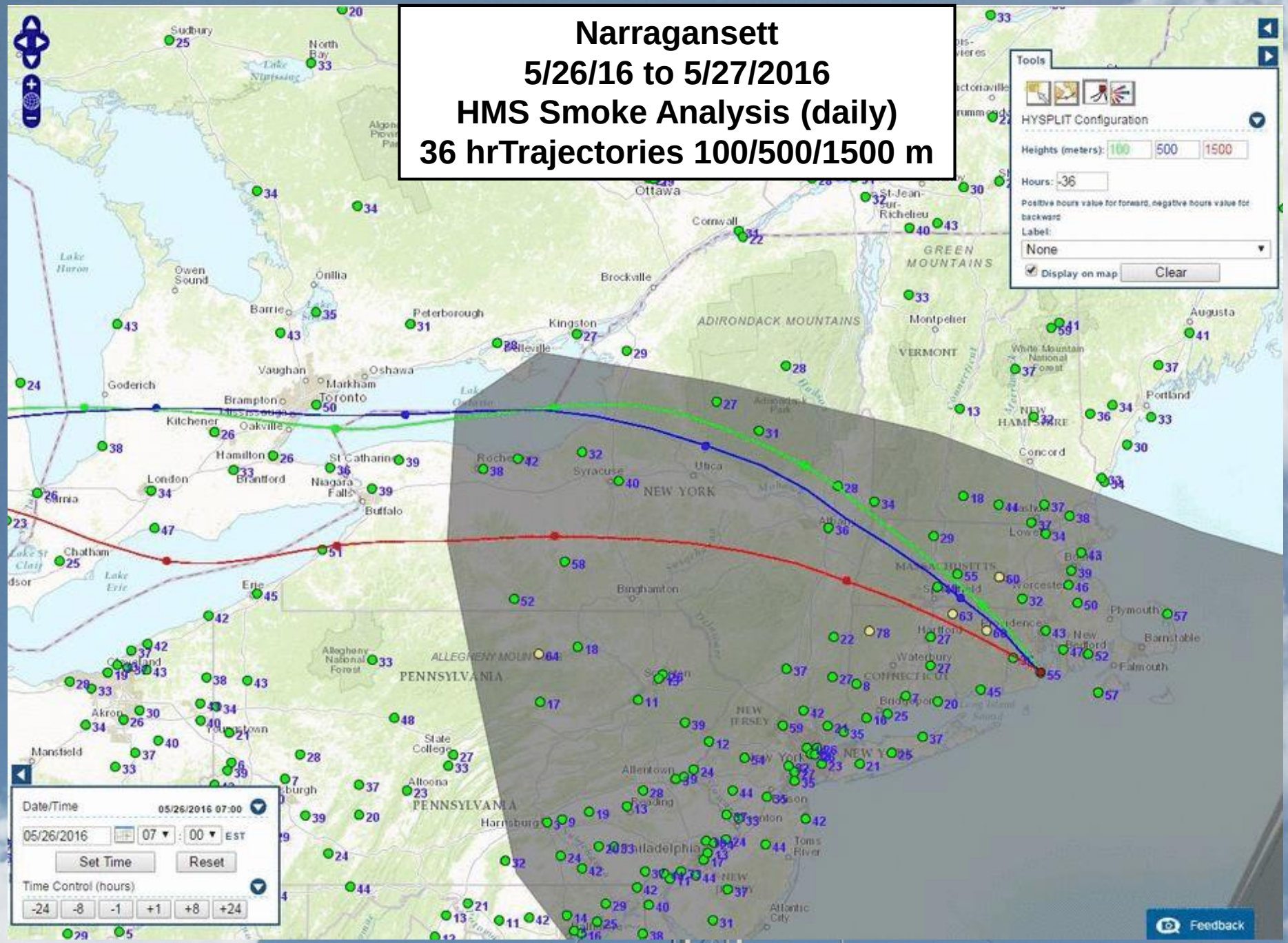
5/25/2016


1800Z SURFACE ANALYSIS
DATE: THU MAY 26 2016
ISSUED: 1925Z THU MAY 26 2016
BY WPC ANALYST KREKELER
COLLABORATING CENTERS: WPC, NHC, OPC

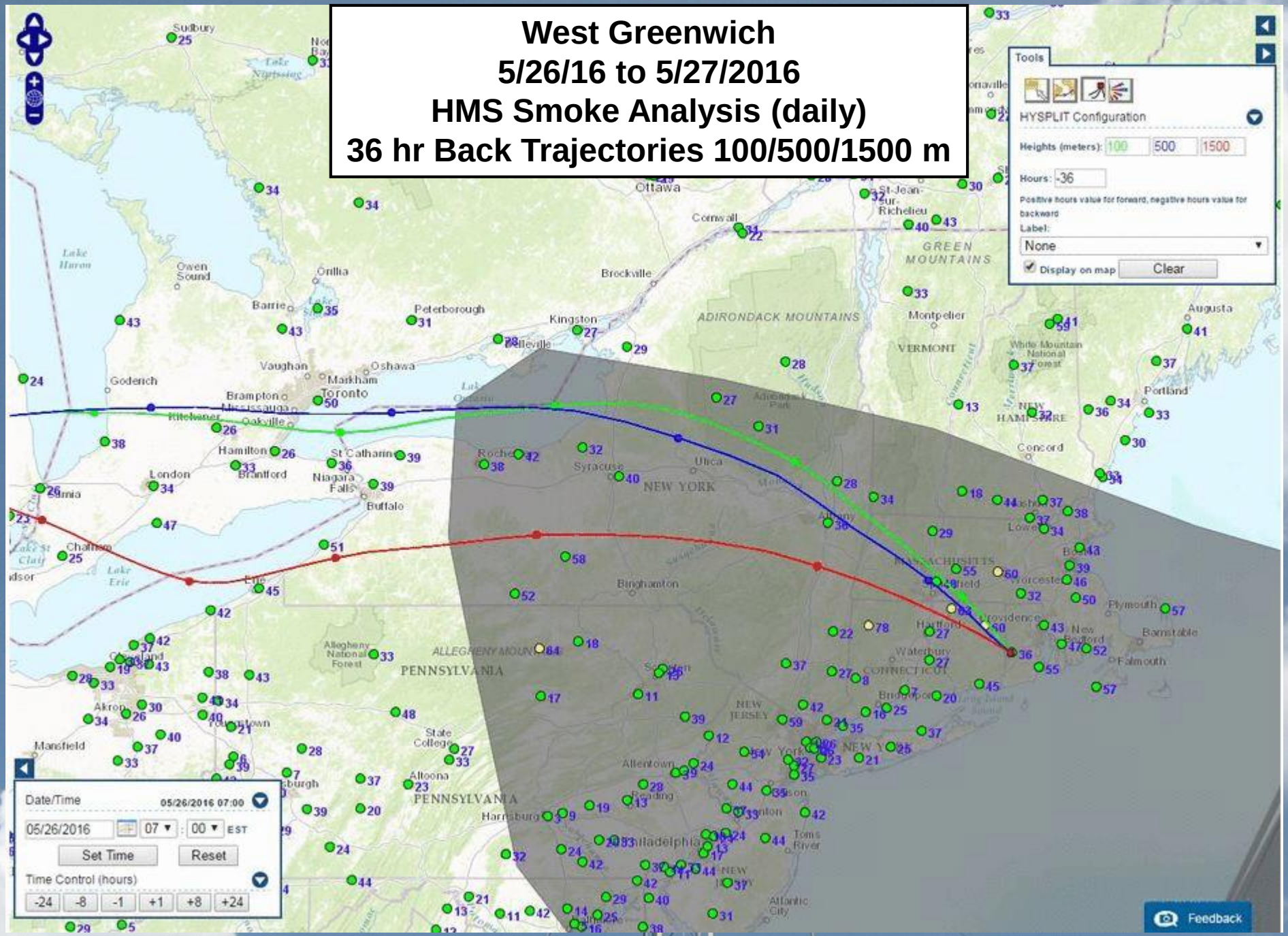

500 mb Heights (dm) / Abs. Vorticity (x10^{-5} s^{-1})
Analysis valid 1200 UTC Thu 26 May 2016
NAM (WRF-NMM) (12z 26 May)
12 15 18 21 24 27 30
x10^{-5} s^{-1}

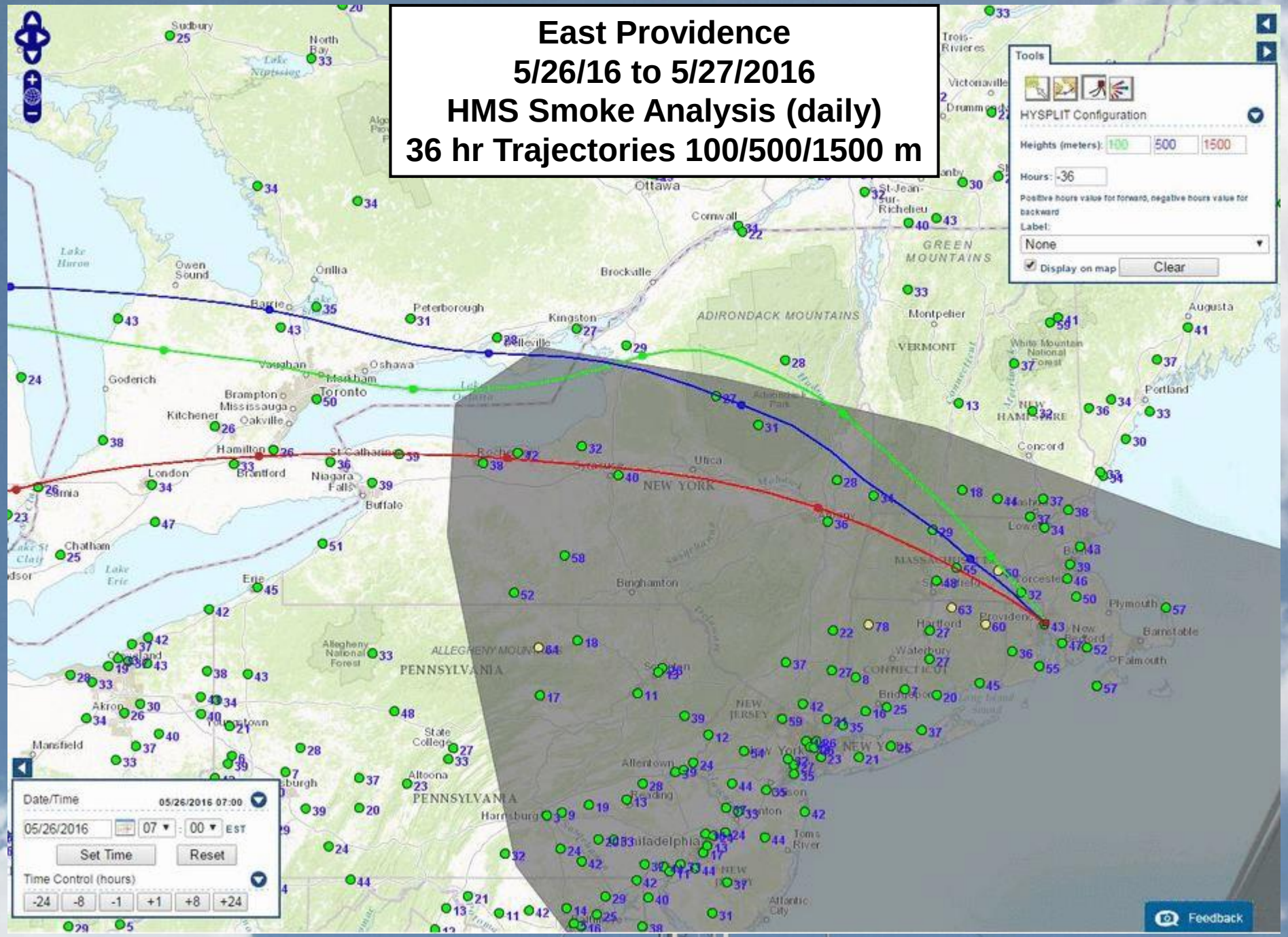

NOAA
National Weather Service
Storm Prediction Center
160526/1200 850 MB UA OBS, HGHTS, TEMPS, Td>=8

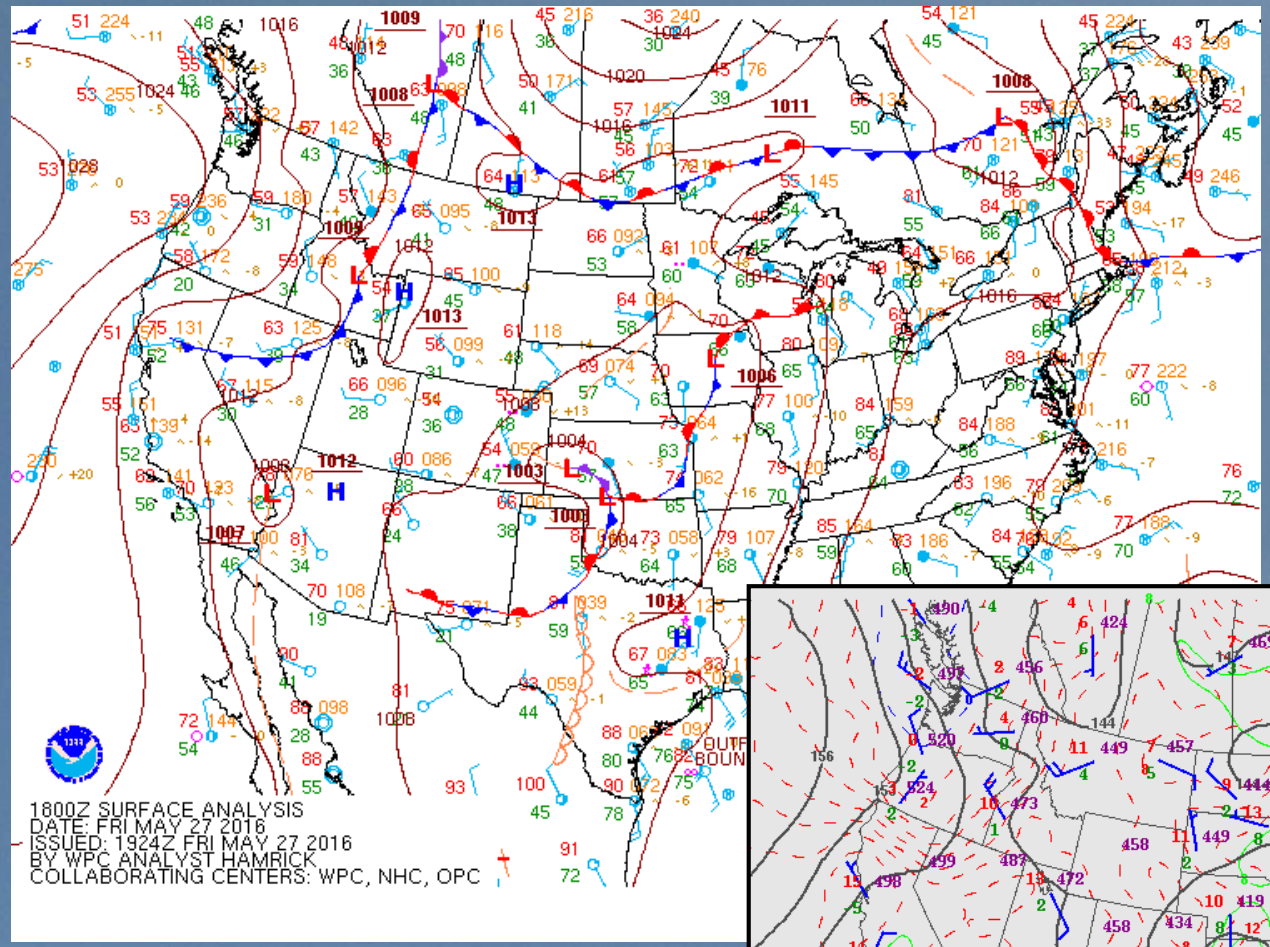
5/26/2016

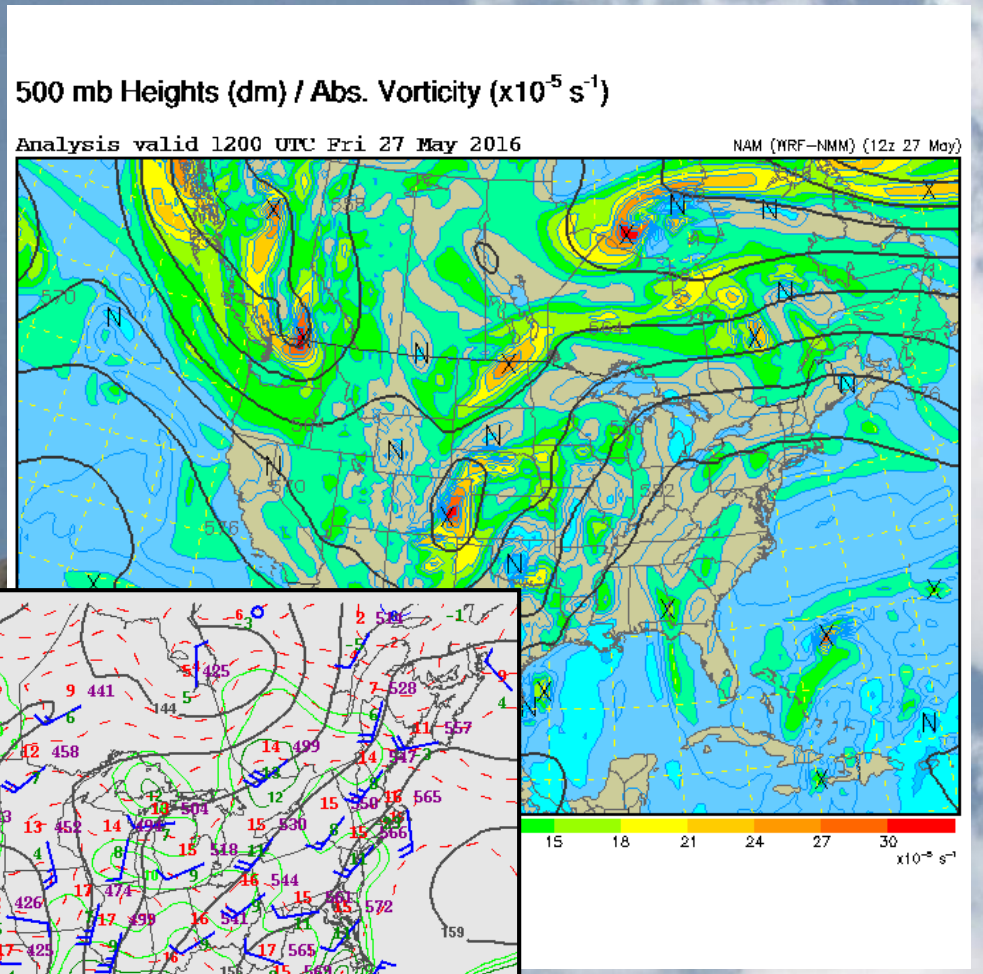

Narragansett
5/26/16 to 5/27/2016
HMS Smoke Analysis (daily)
36 hrTrajectories 100/500/1500 m
Tools
HYSPLIT Configuration
Heights (meters): 100 500 1500
Hours: -36
Positive hours value for forward, negative hours value for backward
Label:
None
Display on map
Clear
Date/Time 05/26/2016 07:00
05/26/2016 07 : 00 EST
Set Time
Reset
Time Control (hours)
-24 -8 -1 +1 +8 +24
Feedback
Ottawa
Montreal
Toronto
Buffalo
Rochester
Syracuse
Albany
Boston
Portland
Augusta
Concord
Montpelier
Burlington
Hartford
Providence
Worcester
Plymouth
Barnstable
Falmouth
Philadelphia
Allentown
Harrisburg
Reading
Scranton
Atlantic City
Binghamton
Utica
Kingston
Peterborough
Barrie
Orillia
Owen Sound
Goderich
Kitchener
Hamilton
London
Sarnia
Chatham
Erie
Cleveland
Akron
Mansfield
Youngstown
State College
Altoona
Pittsburgh
Brockville
Cornwall
St-Jean-sur-Richelieu
Belleville
Oshawa
Markham
Vaughan
Brampton
Oakville
St Catharines
Niagara Falls
Brantford
NEW YORK
PENNSYLVANIA
NEW JERSEY
CONNECTICUT
MASSACHUSETTS
VERMONT
NEW HAMPSHIRE
ADIRONDACK MOUNTAINS
GREEN MOUNTAINS
Lake Huron
Lake Erie
Lake Ontario
Lake St Clair
Allegheny National Forest
White Mountain National Forest

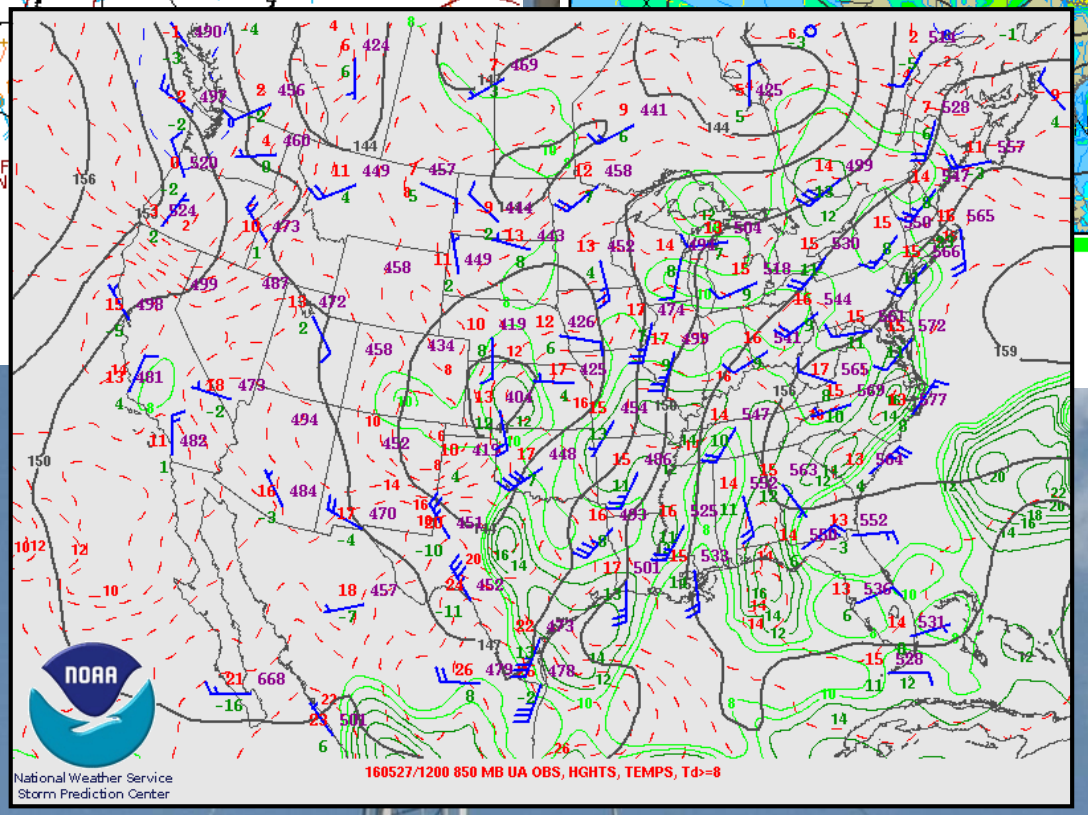
West Greenwich
5/26/16 to 5/27/2016
HMS Smoke Analysis (daily)
36 hr Back Trajectories 100/500/1500 m



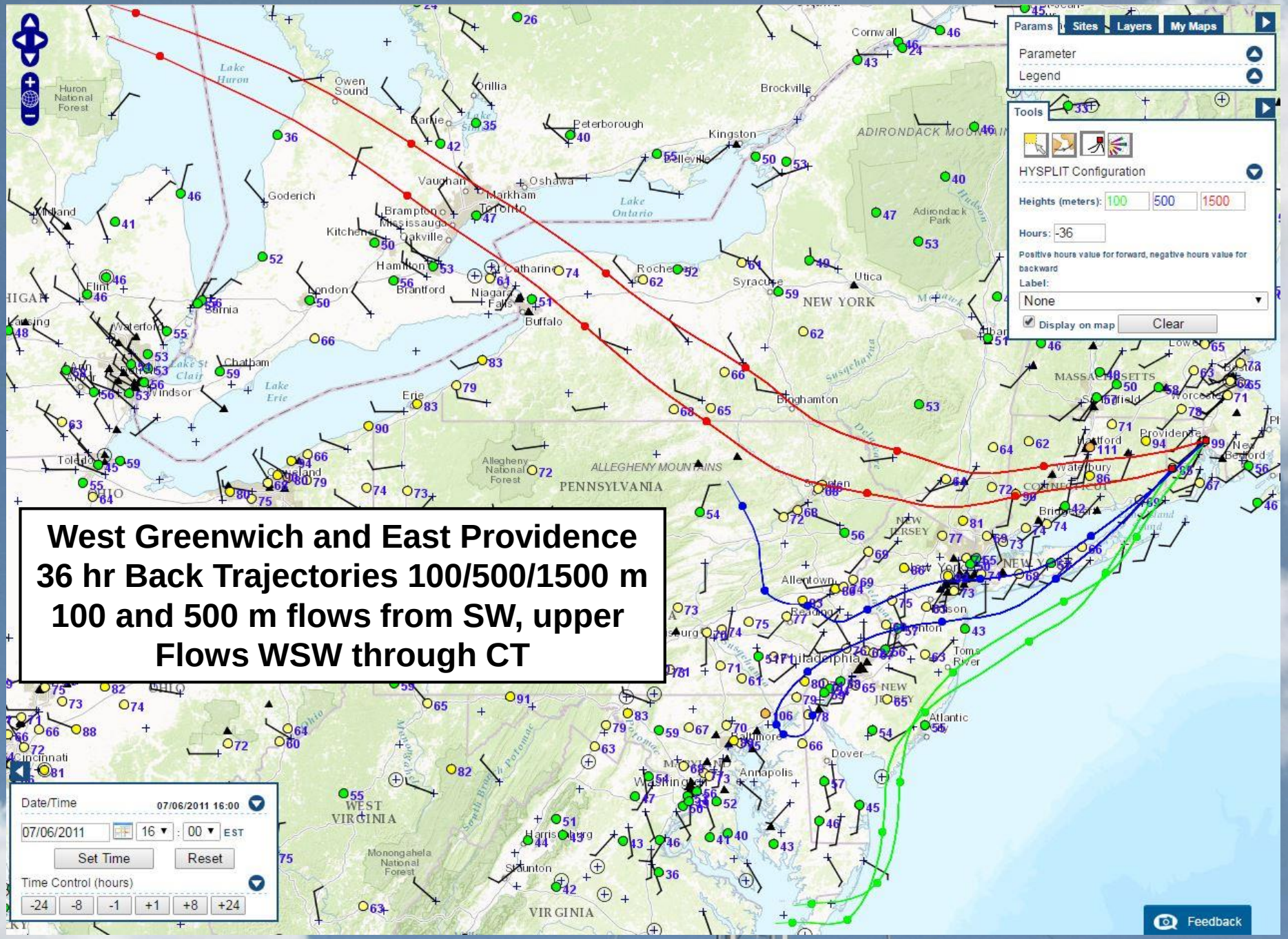

East Providence
5/26/16 to 5/27/2016
HMS Smoke Analysis (daily)
36 hr Trajectories 100/500/1500 m
Tools
HYSPLIT Configuration
Heights (meters): 100 500 1500
Hours: -36
Positive hours value for forward, negative hours value for backward
Label:
None
Display on map
Clear
Date/Time 05/26/2016 07:00
05/26/2016 07 : 00 EST
Set Time
Reset
Time Control (hours)
-24 -8 -1 +1 +8 +24
Feedback


1800Z SURFACE ANALYSIS
DATE: FRI MAY 27 2016
ISSUED: 1924Z FRI MAY 27 2016
BY WPC ANALYST HAMRICK
COLLABORATING CENTERS: WPC, NHC, OPC


500 mb Heights (dm) / Abs. Vorticity (x10^{-5} s^{-1})
Analysis valid 1200 UTC Fri 27 May 2016
NAM (WRF-NMM) (12z 27 May)
15 18 21 24 27 30
x10^{-5} s^{-1}


National Weather Service
Storm Prediction Center
160527/1200 850 MB UA OBS, HGHTS, TEMPS, Td>=8

5/27/16



West Greenwich and East Providence 36 hr Back Trajectories 100/500/1500 m 100 and 500 m flows from SW, upper Flows WSW through CT

7/6/2011

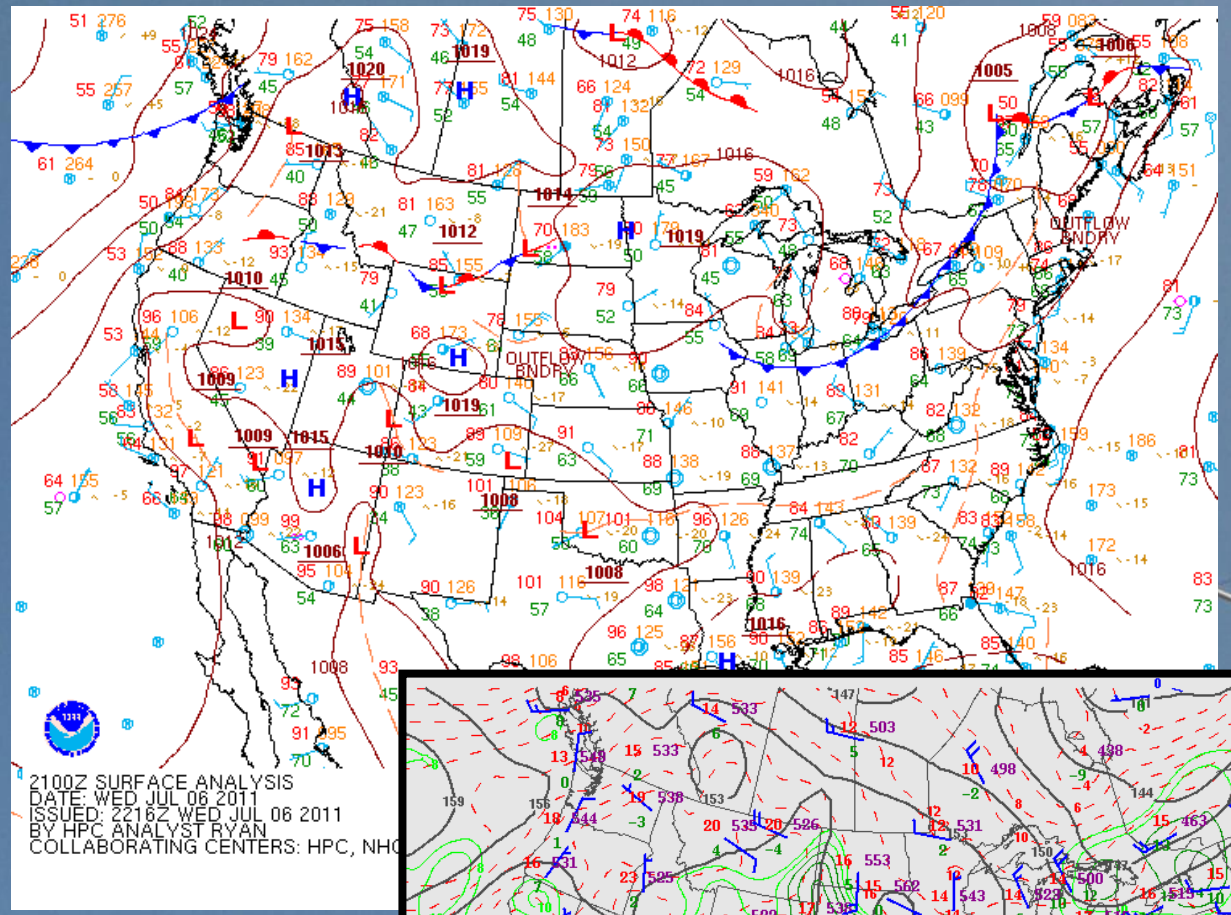
Non Event Comparison

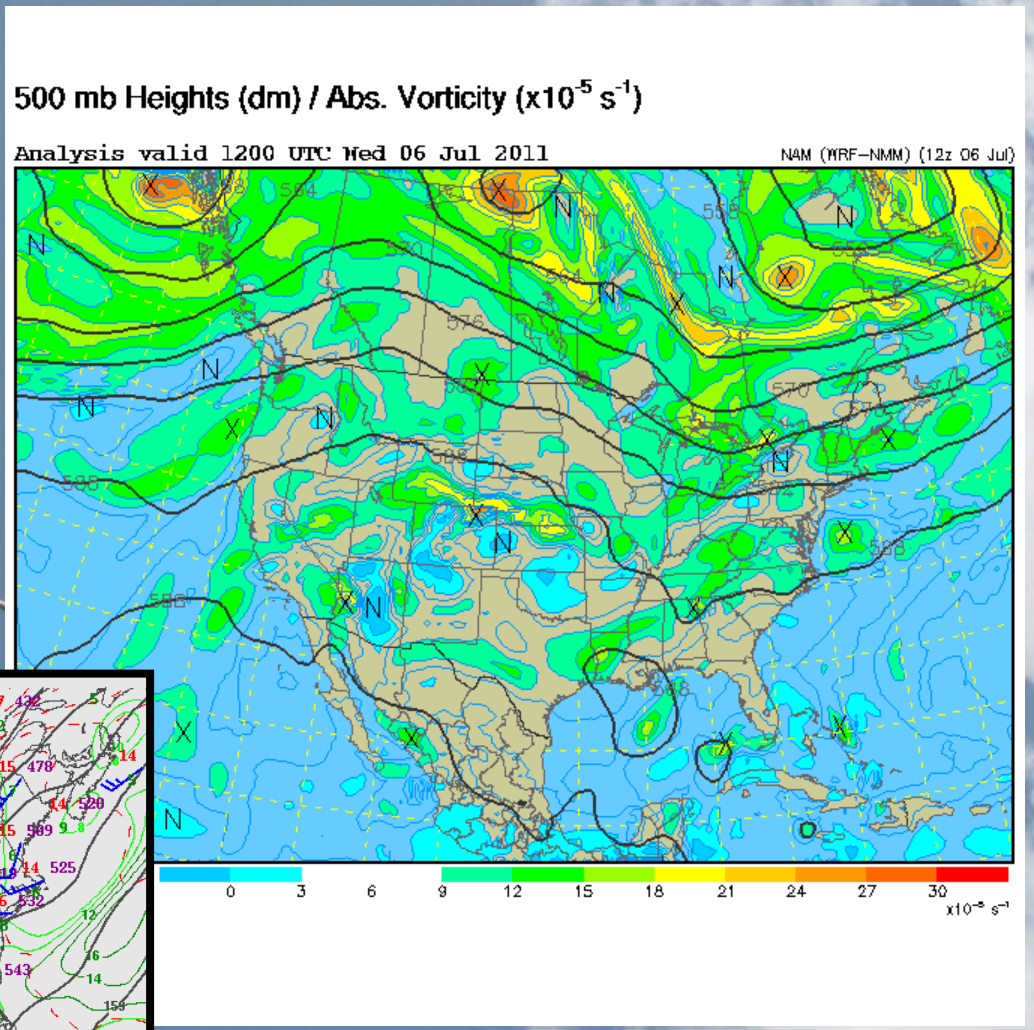
Max 8-hr Ozone

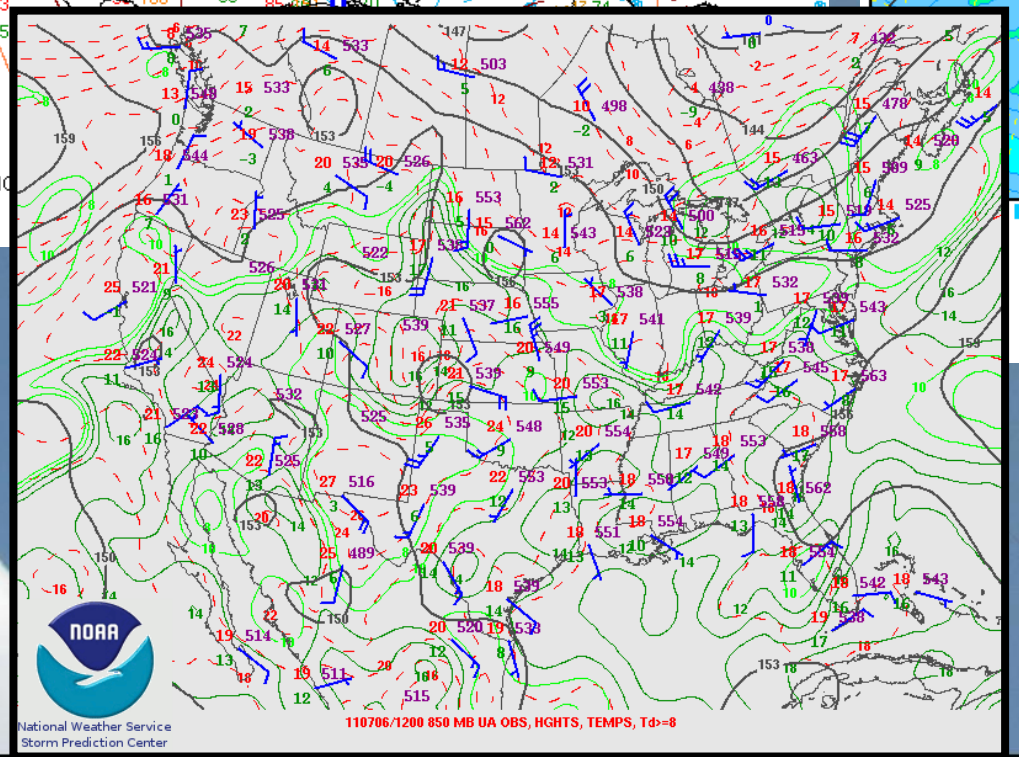
West Greenwich 84 ppb

East Providence 78 ppb

Narragansett 69 ppb

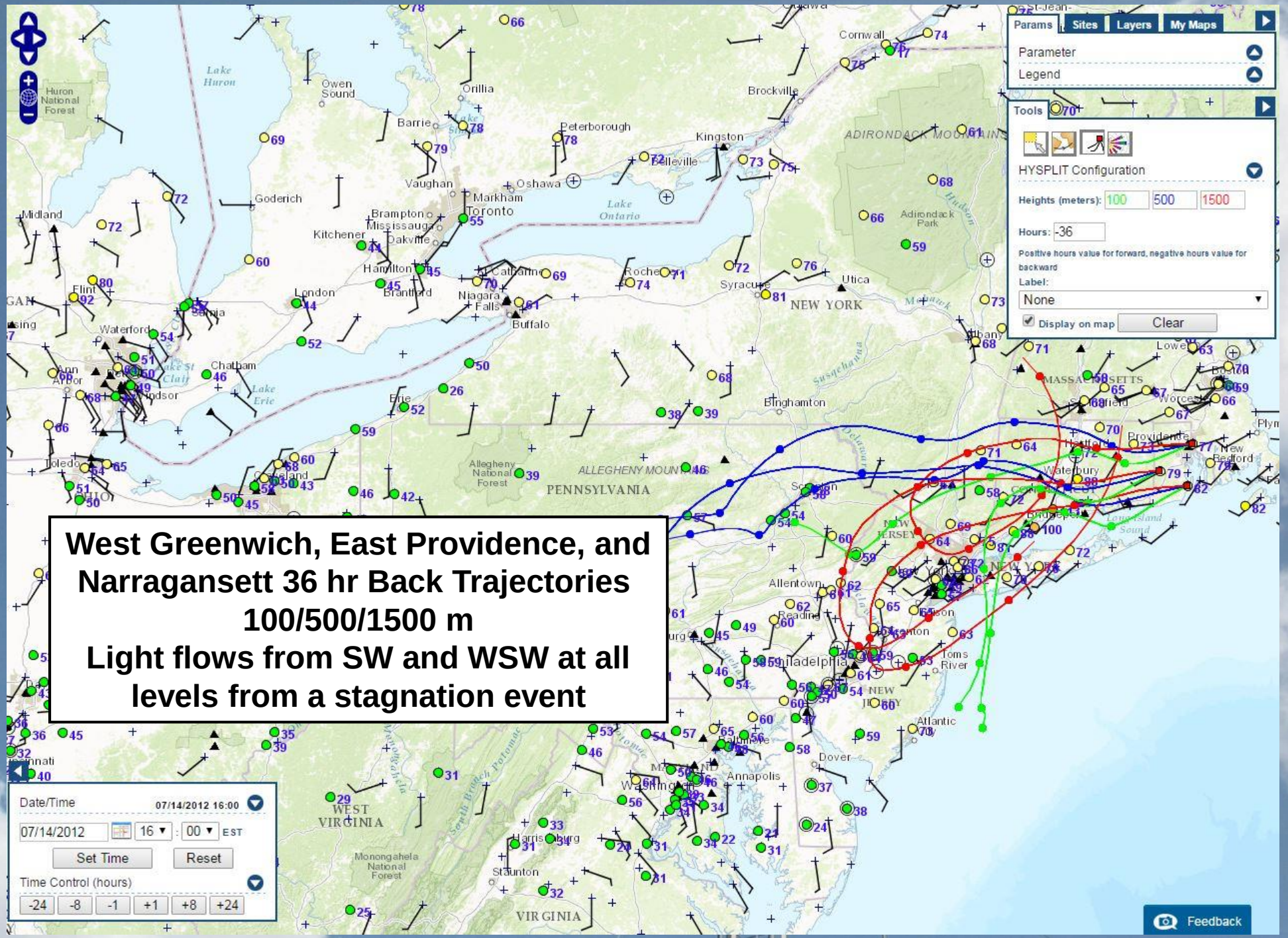






7/6/2011

Non Event Comparison



7/14/2012

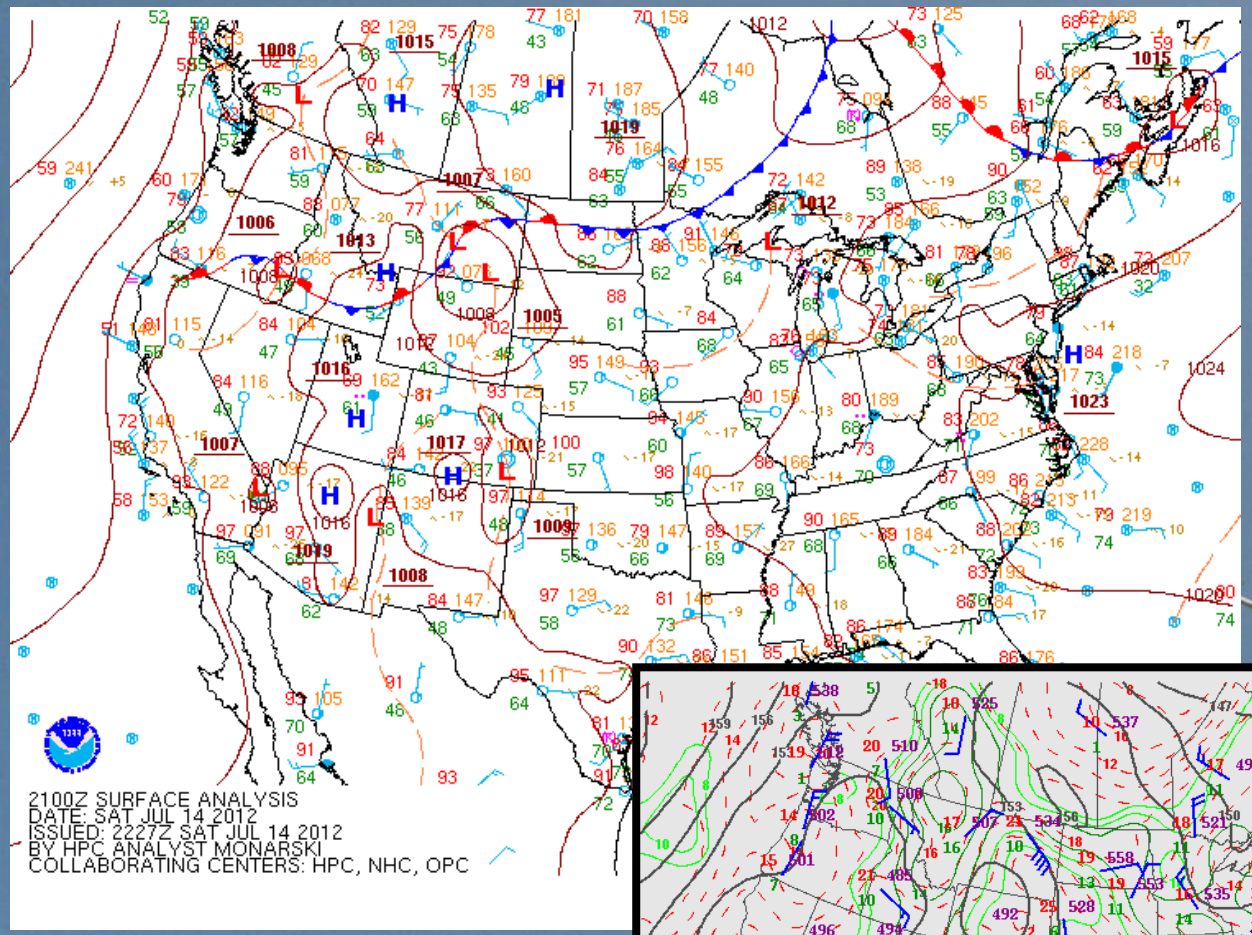
Non Event Comparison

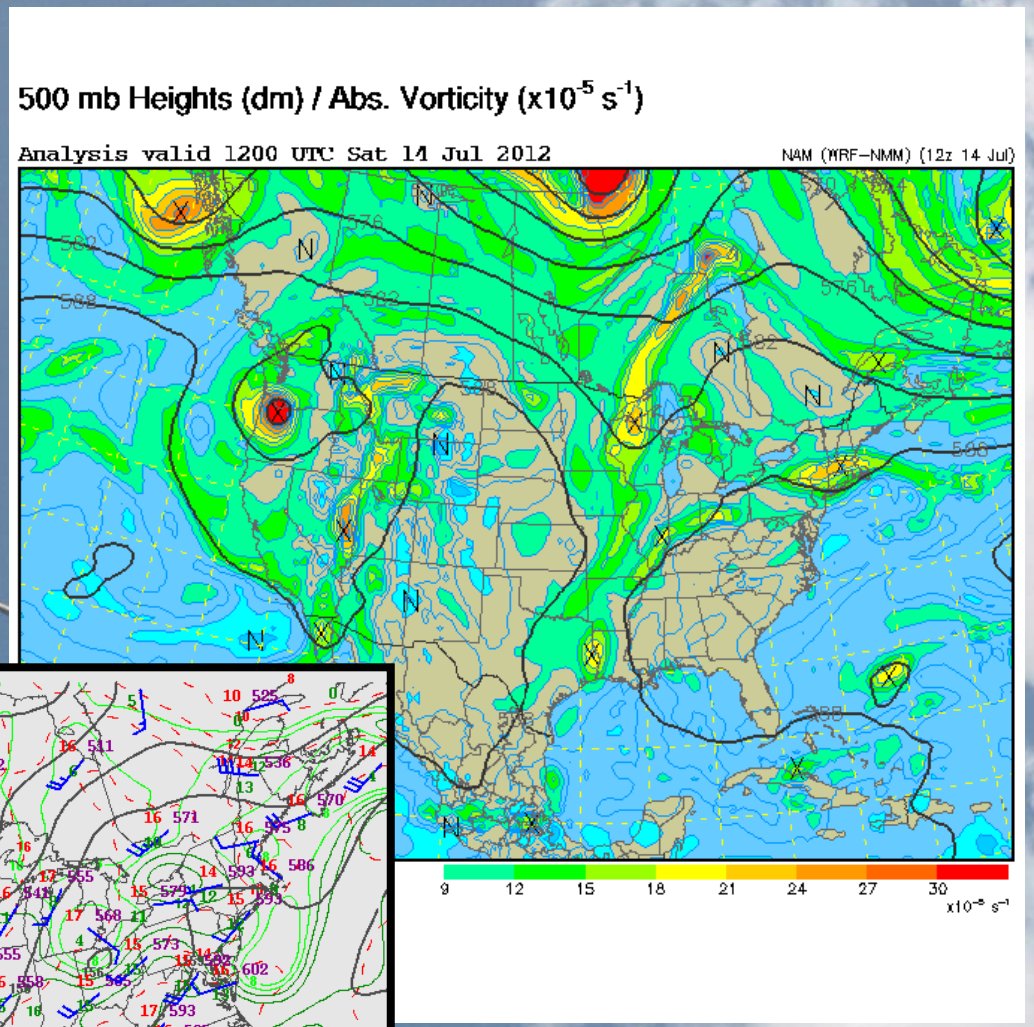
Max 8-hr Ozone

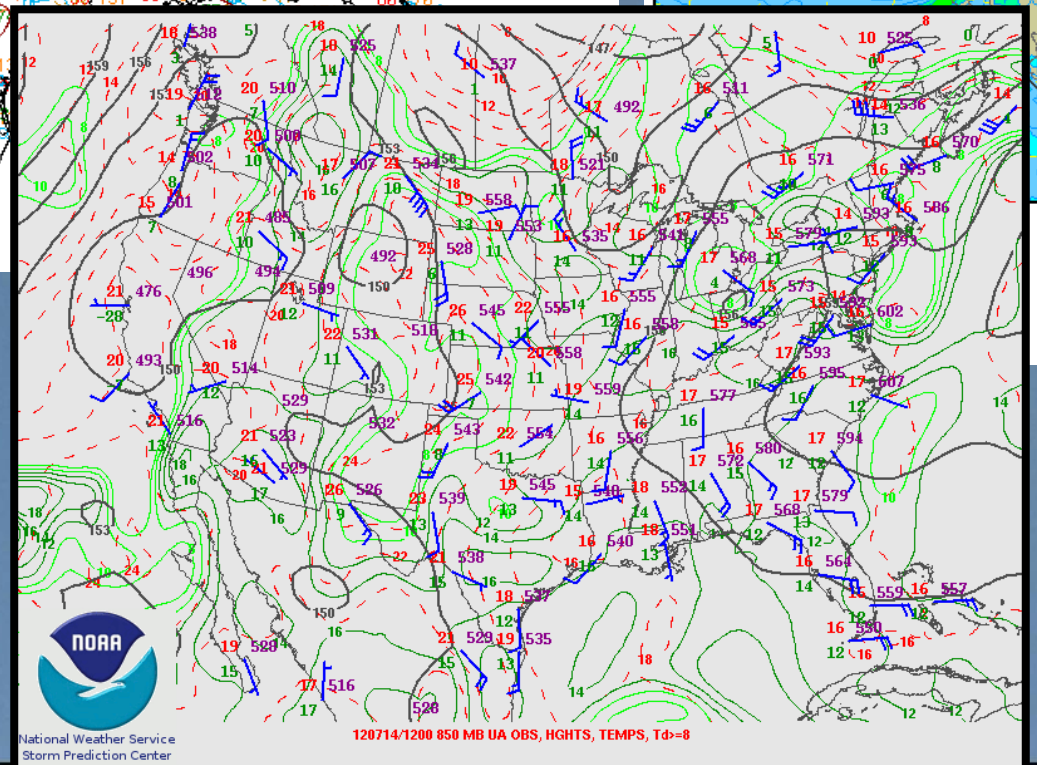
Narragansett 81 ppb

East Providence 79 ppb

West Greenwich 71 ppb







7/14/2012

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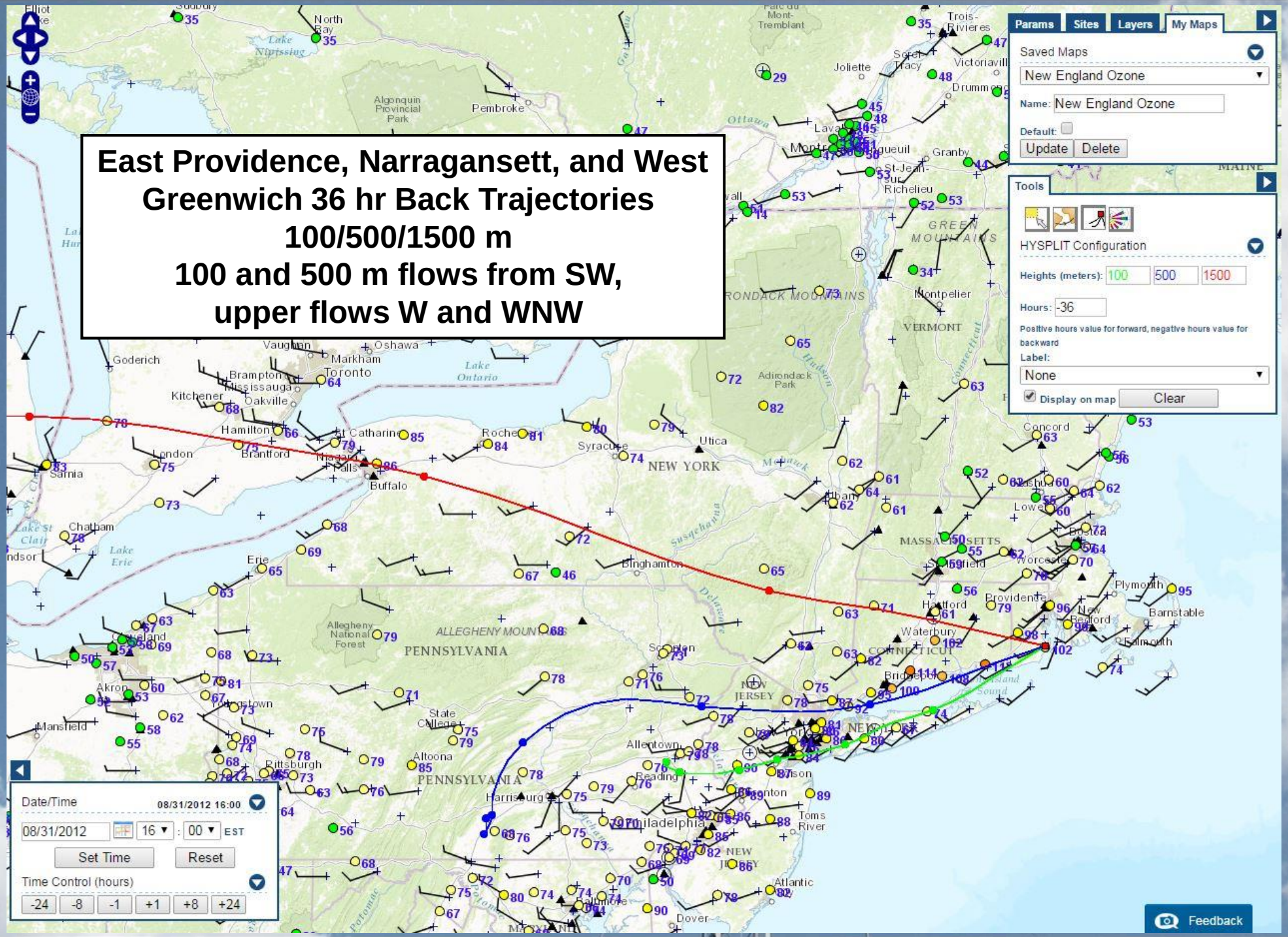


8/31/2012

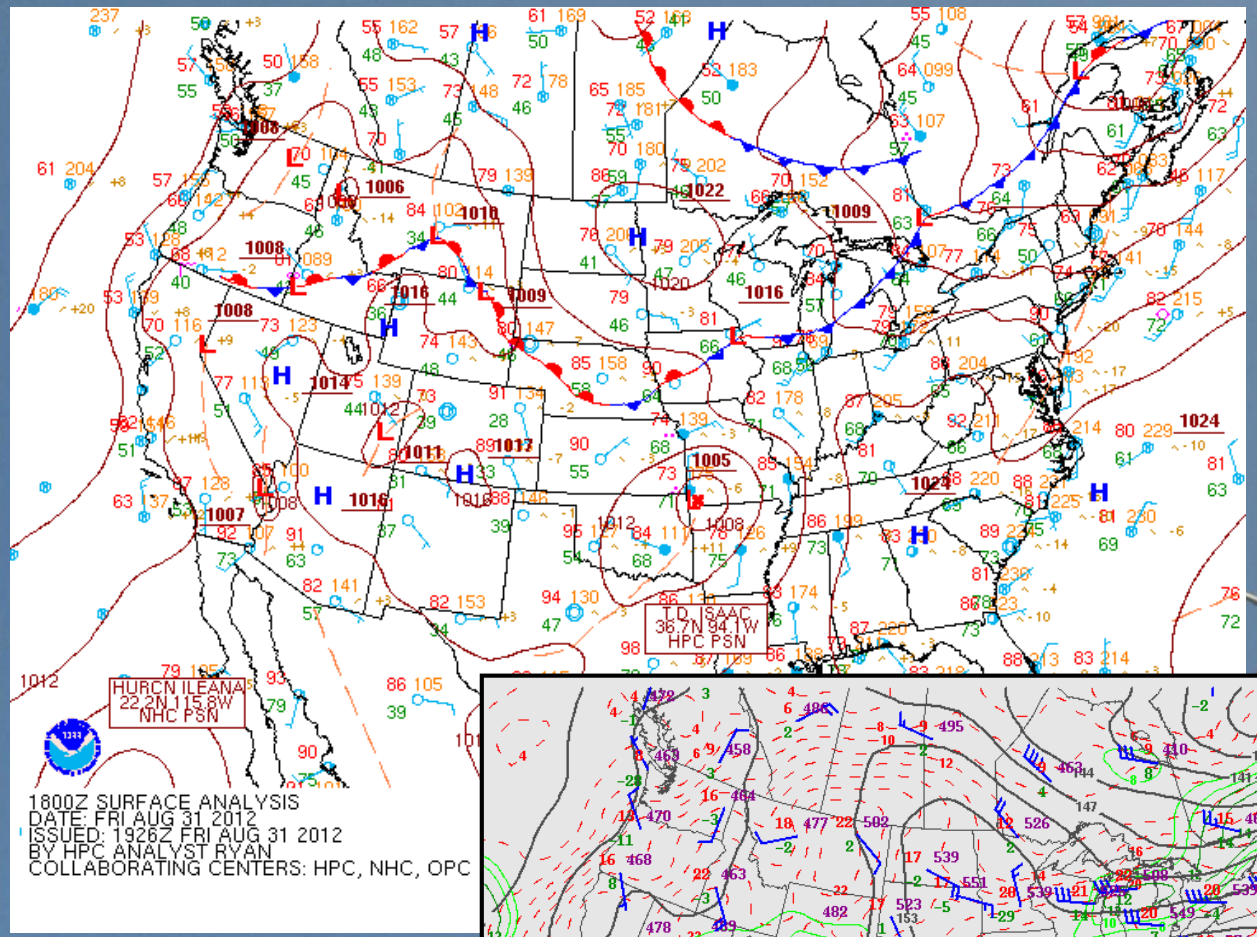
Non Event Comparison

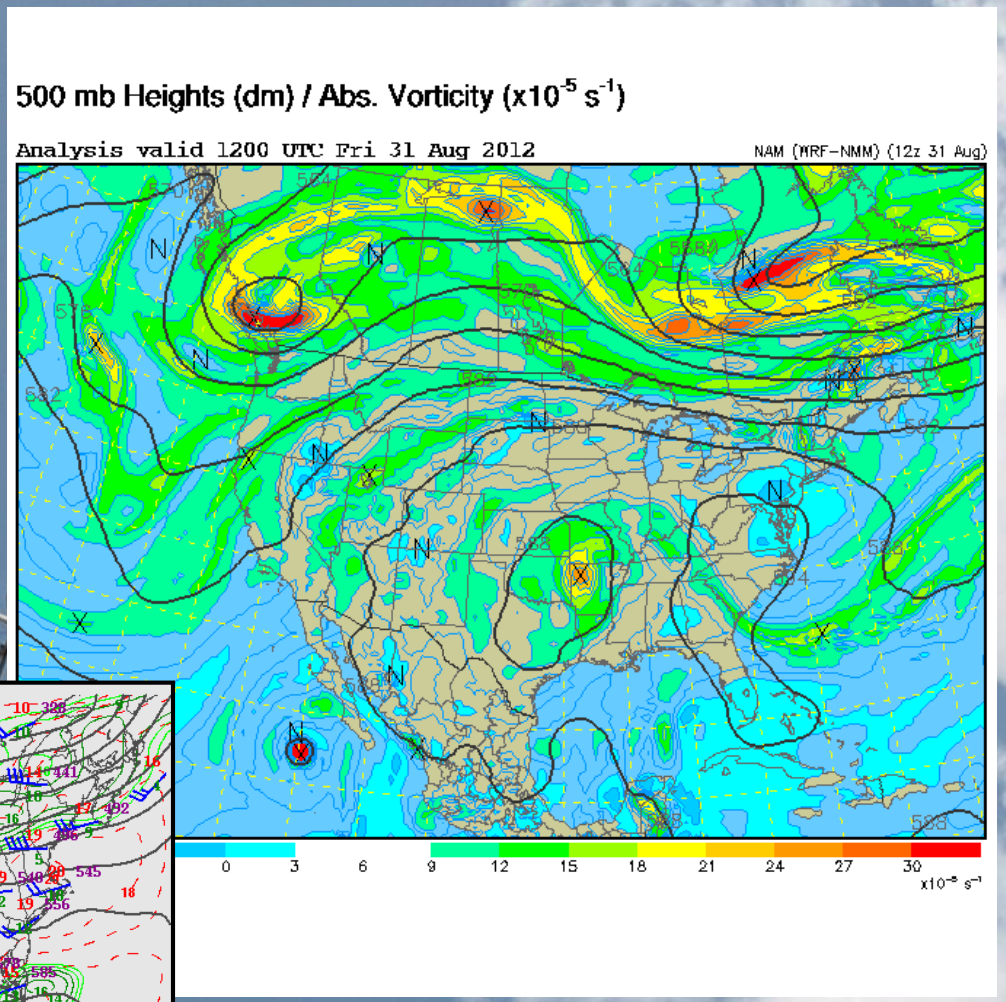
Max 8-hr Ozone

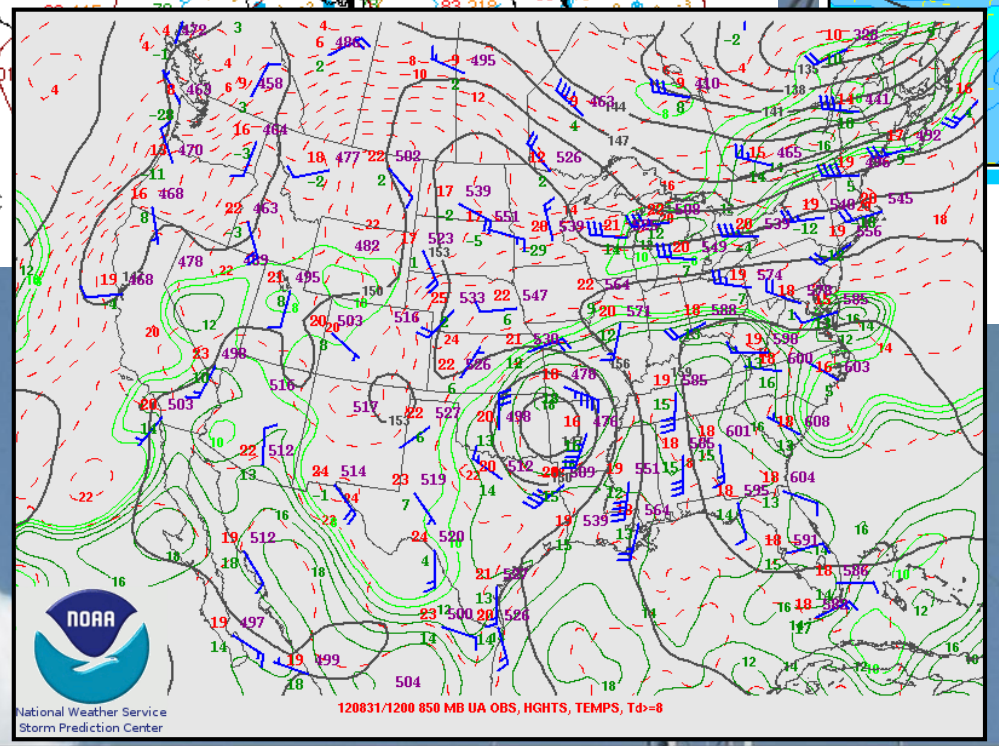
East Providence 92 ppb

Narragansett 84 ppb

West Greenwich 78 ppb

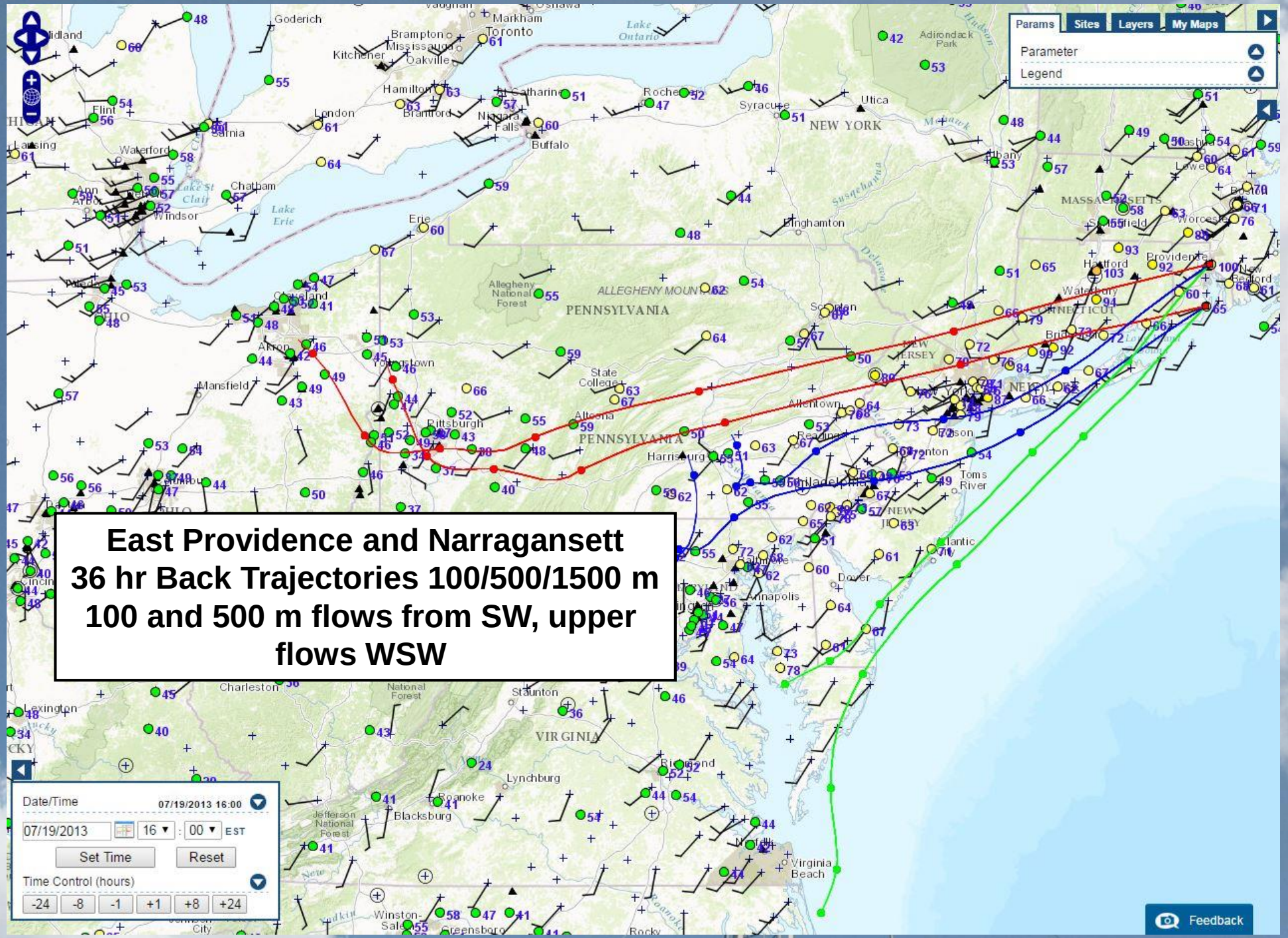






8/31/2012

Non Event Comparison



7/19/2013

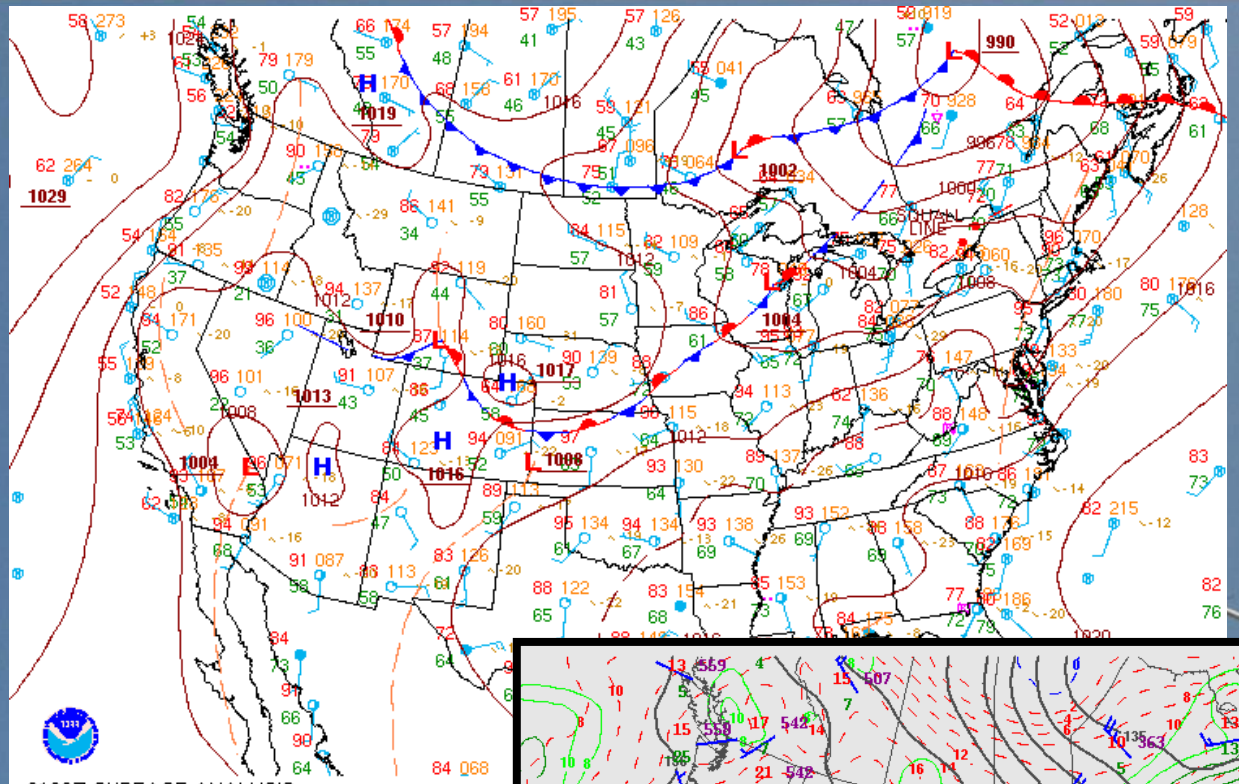
Non Event Comparison

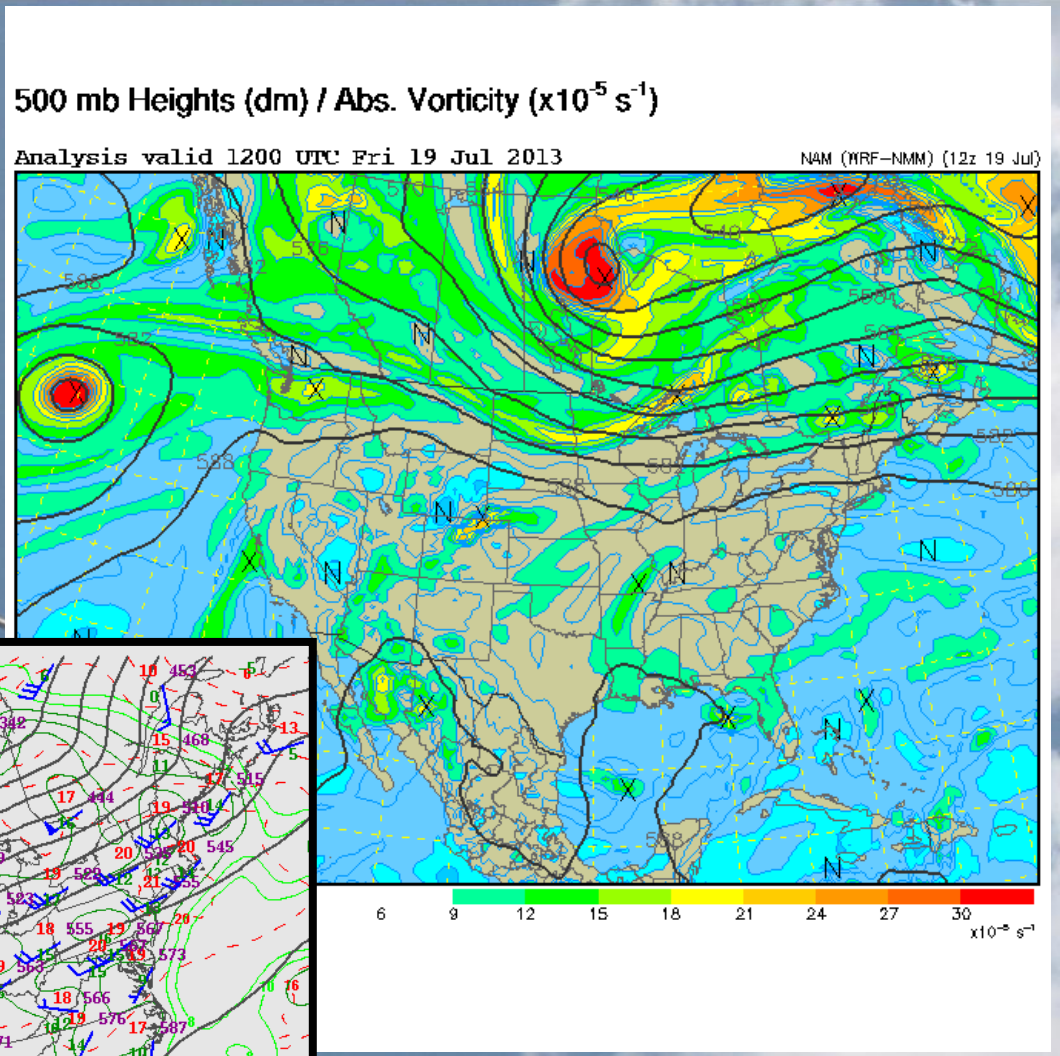
Max 8-hr Ozone

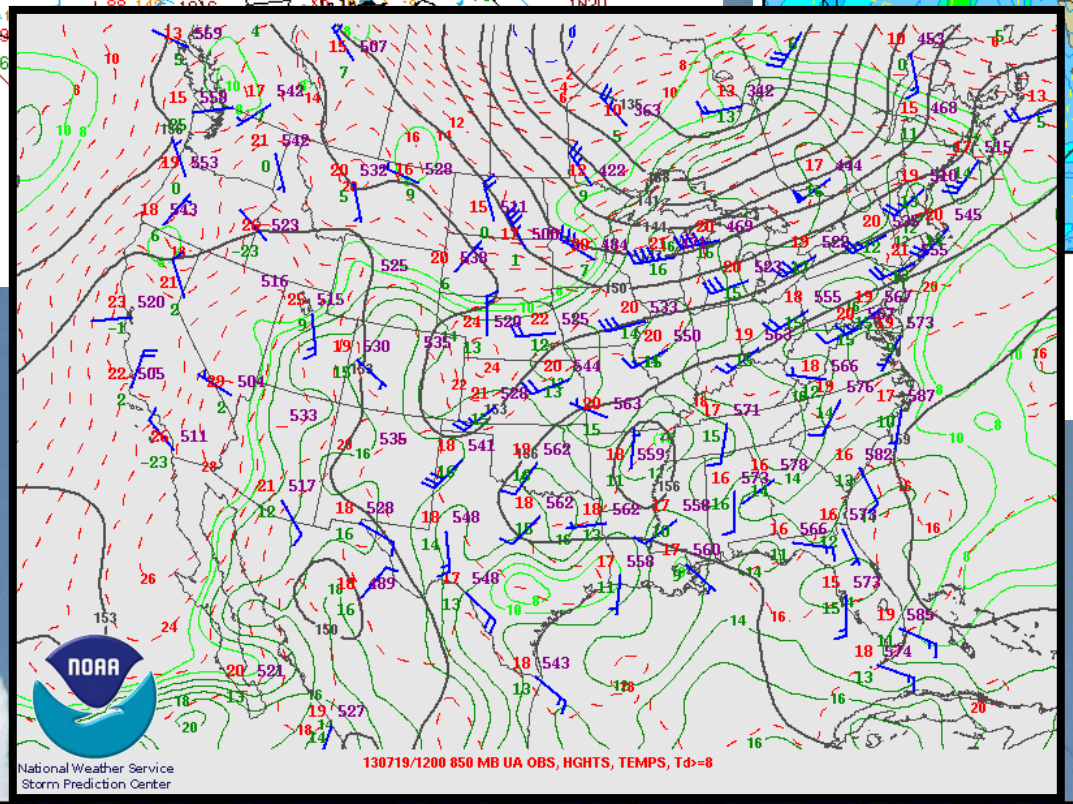
East Providence 80 ppb

Narragansett 73 ppb

West Greenwich 65 ppb

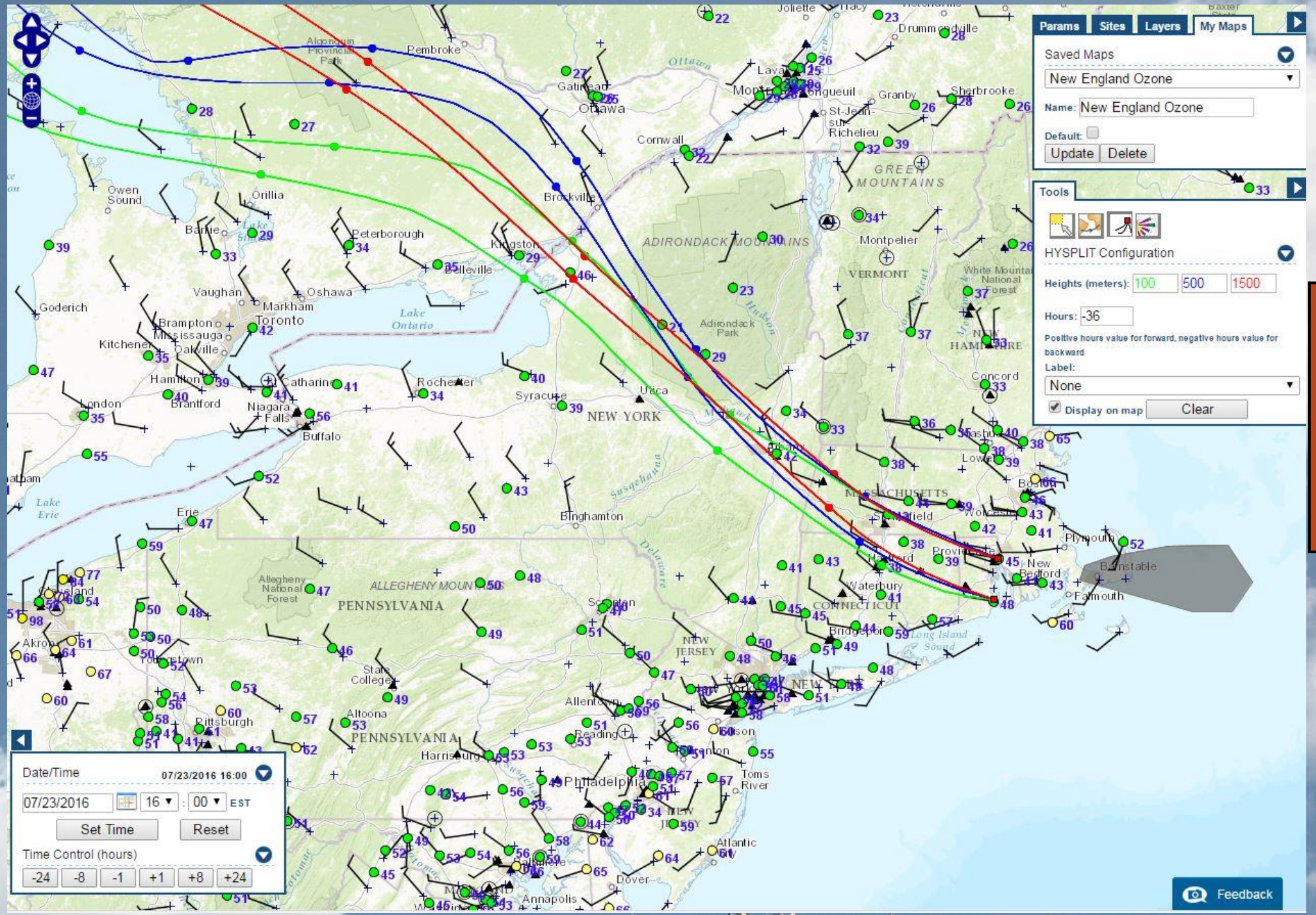






7/19/2013

Non Event Comparison



Matching Day Analysis

7/23/2016

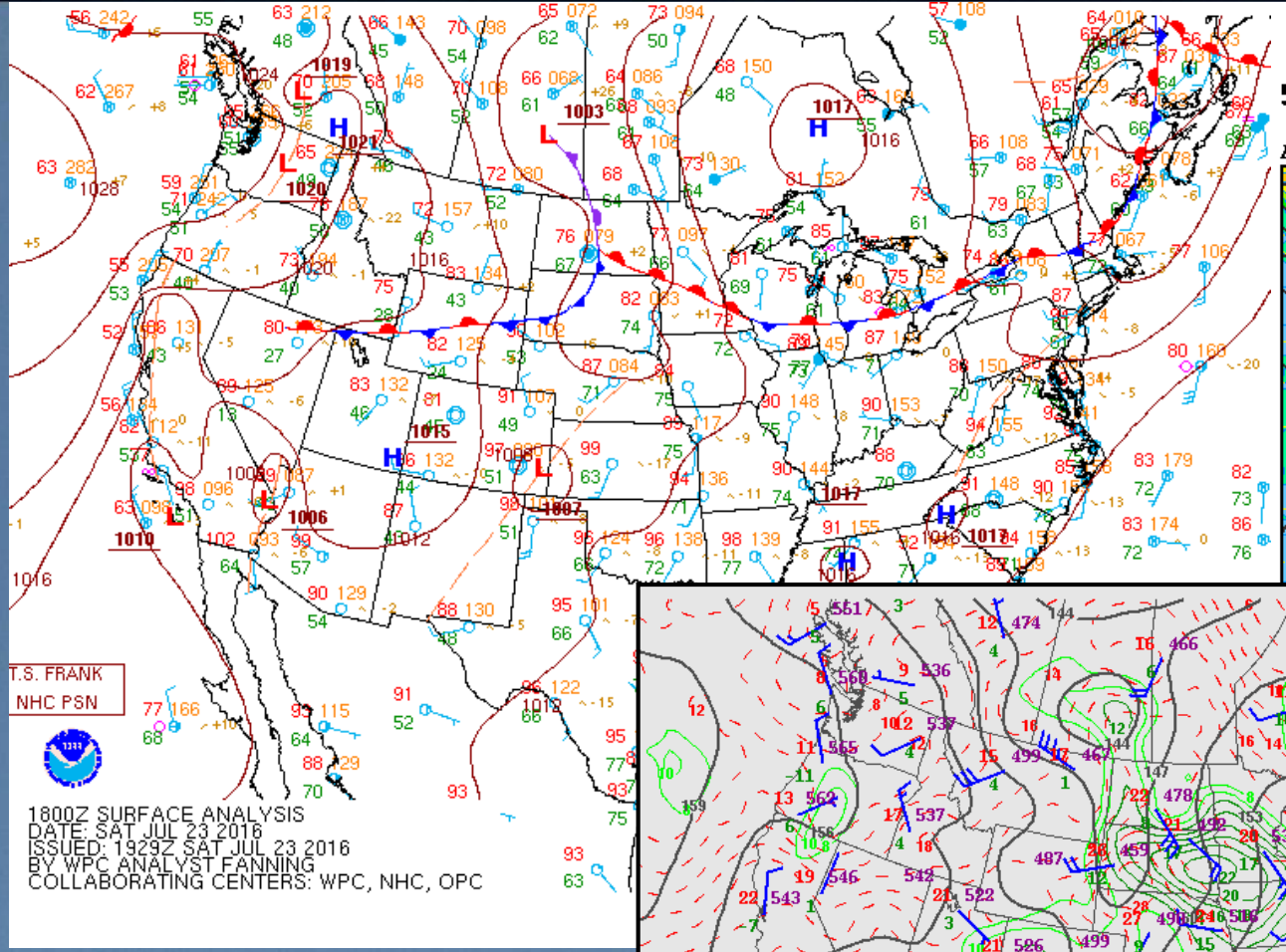
Max 8-hr Ozone

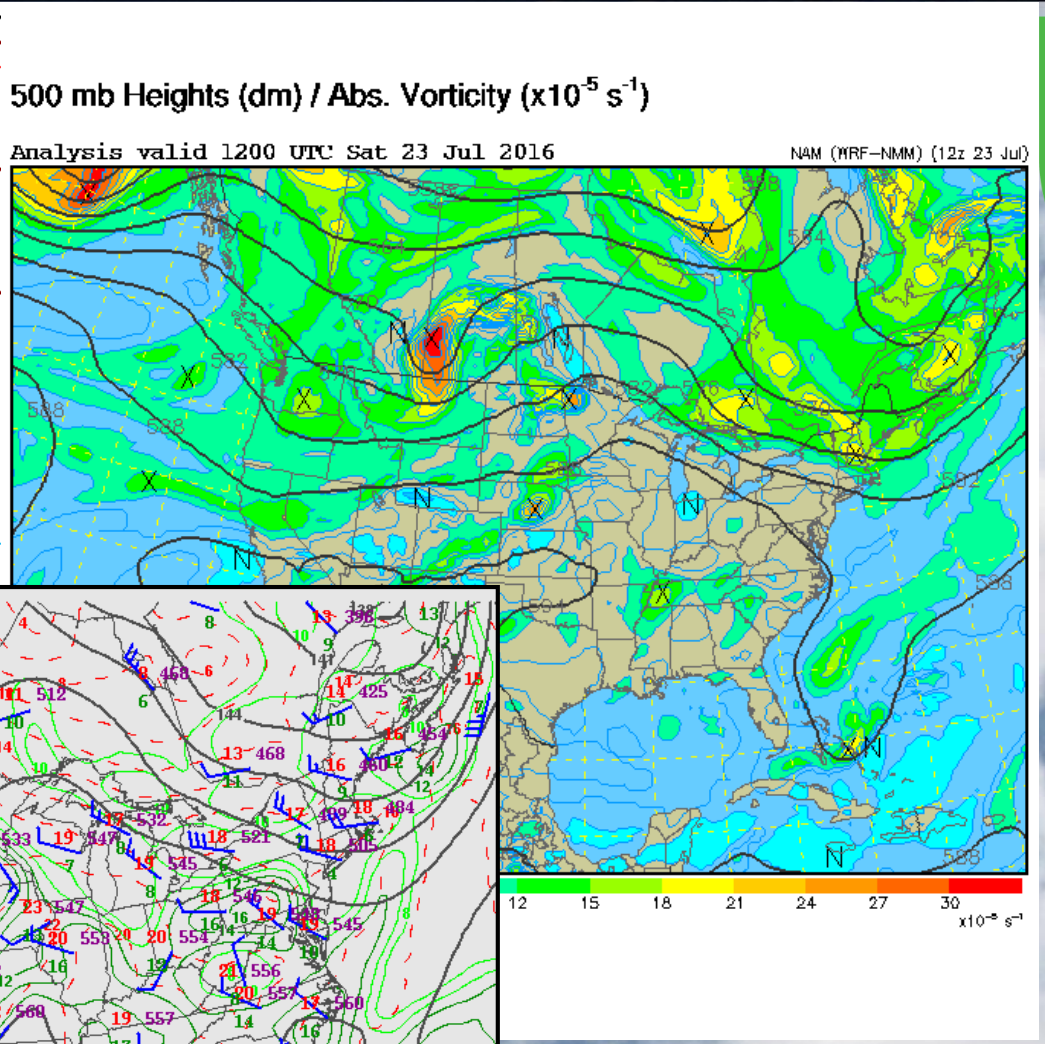
East Providence 43 ppb

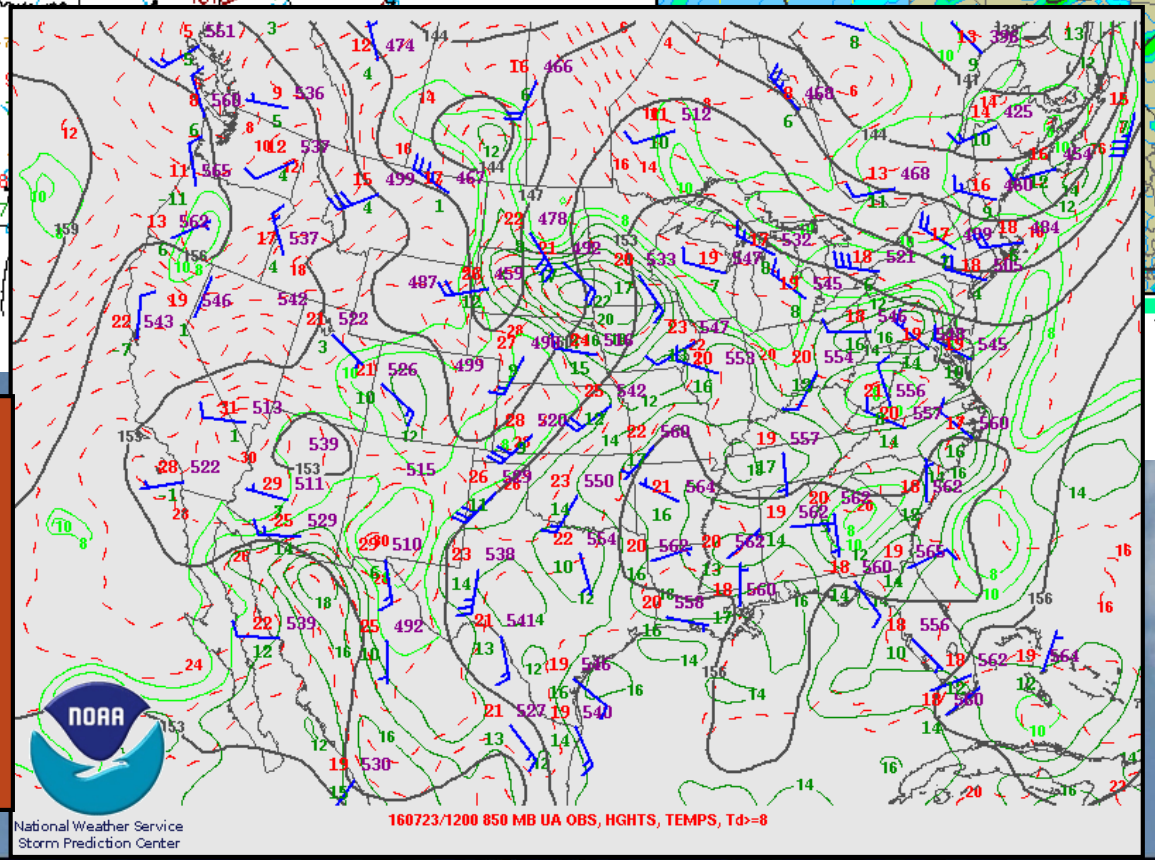
Narragansett 42 ppb

West Greenwich 39 ppb

TF Green High Temp 93F



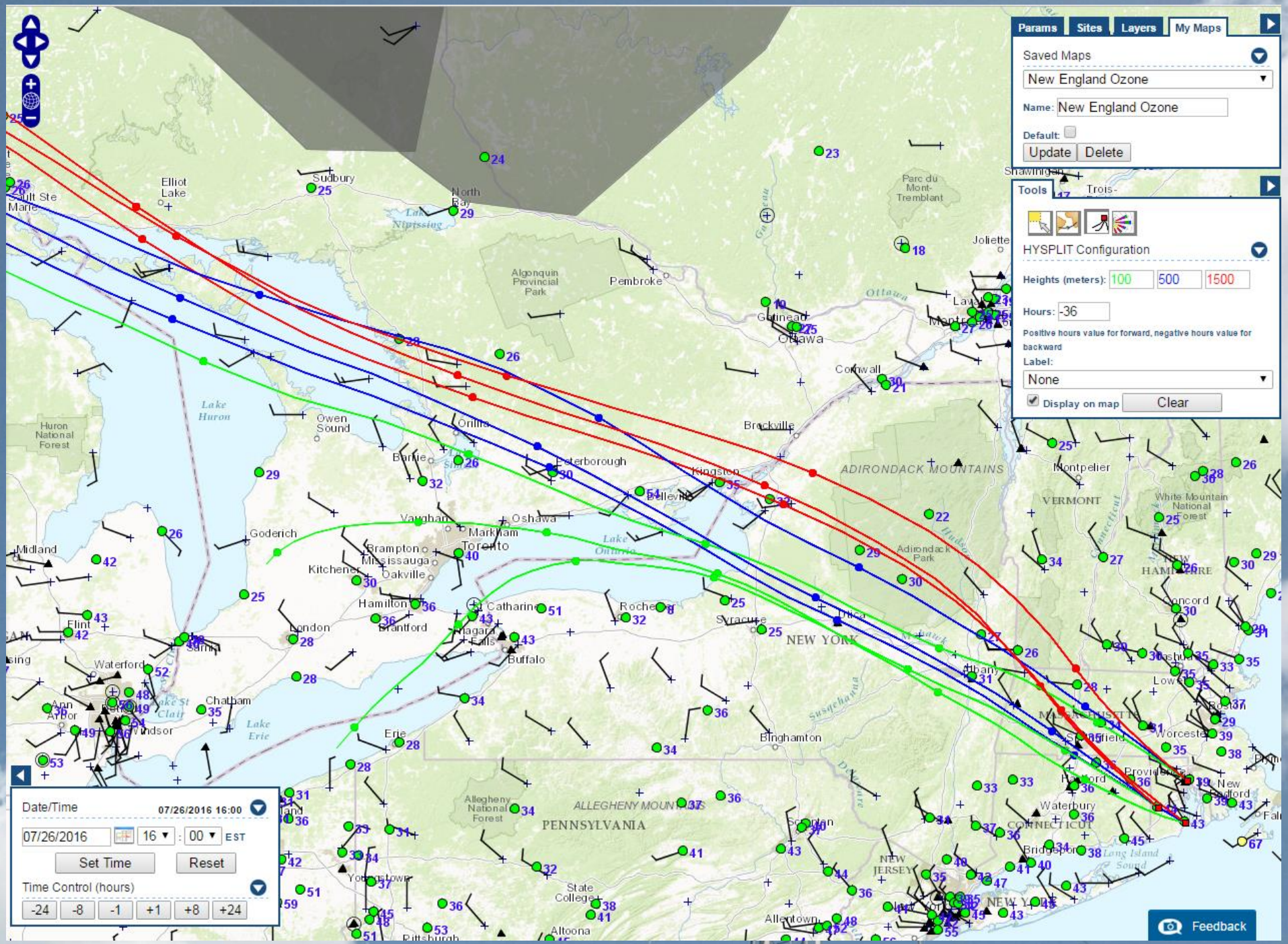




Matching Day Analysis

7/23/2016

Trough axis to the east of Rhode Island. NW flows at 850 mb to 500 mb. Cold front to the N and NW. Partly cloud skies, no precipitation.



Matching Day Analysis

7/26/2016

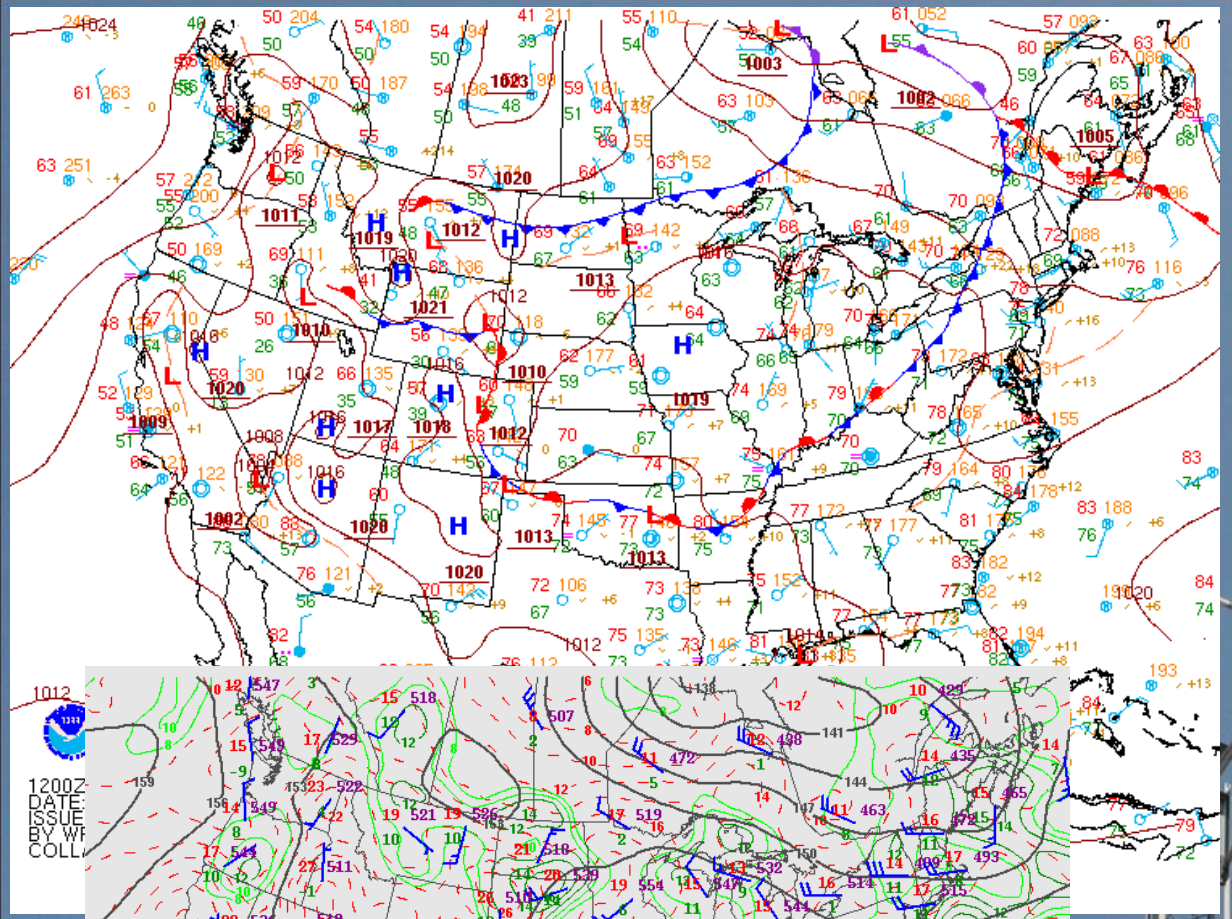
Max 8-hr Ozone

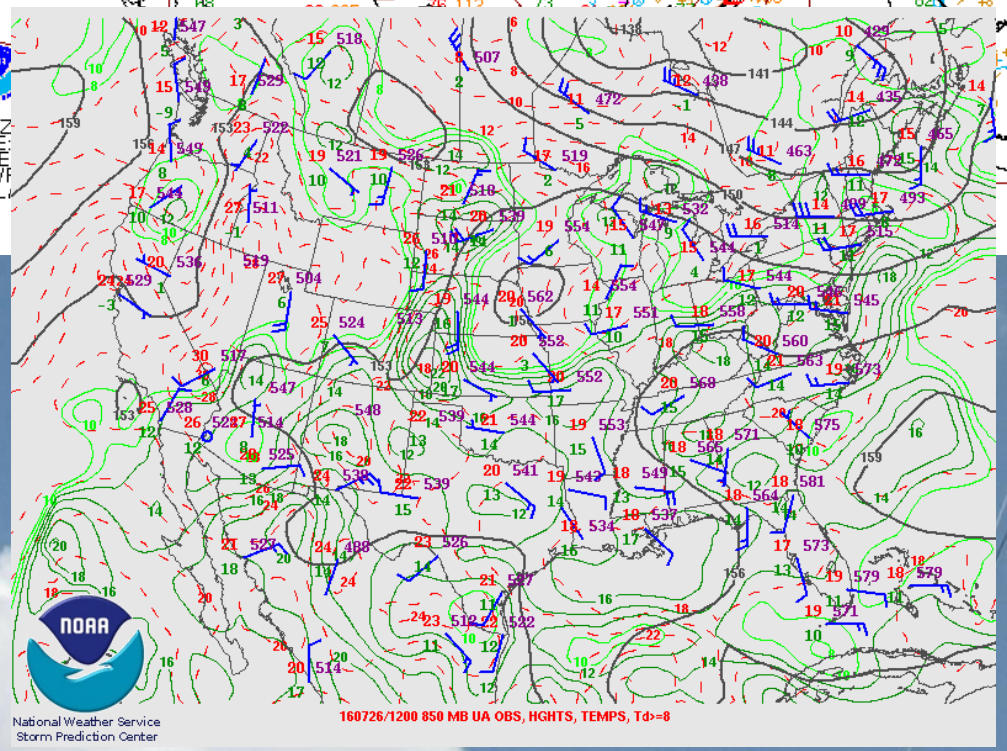
East Providence 43 ppb

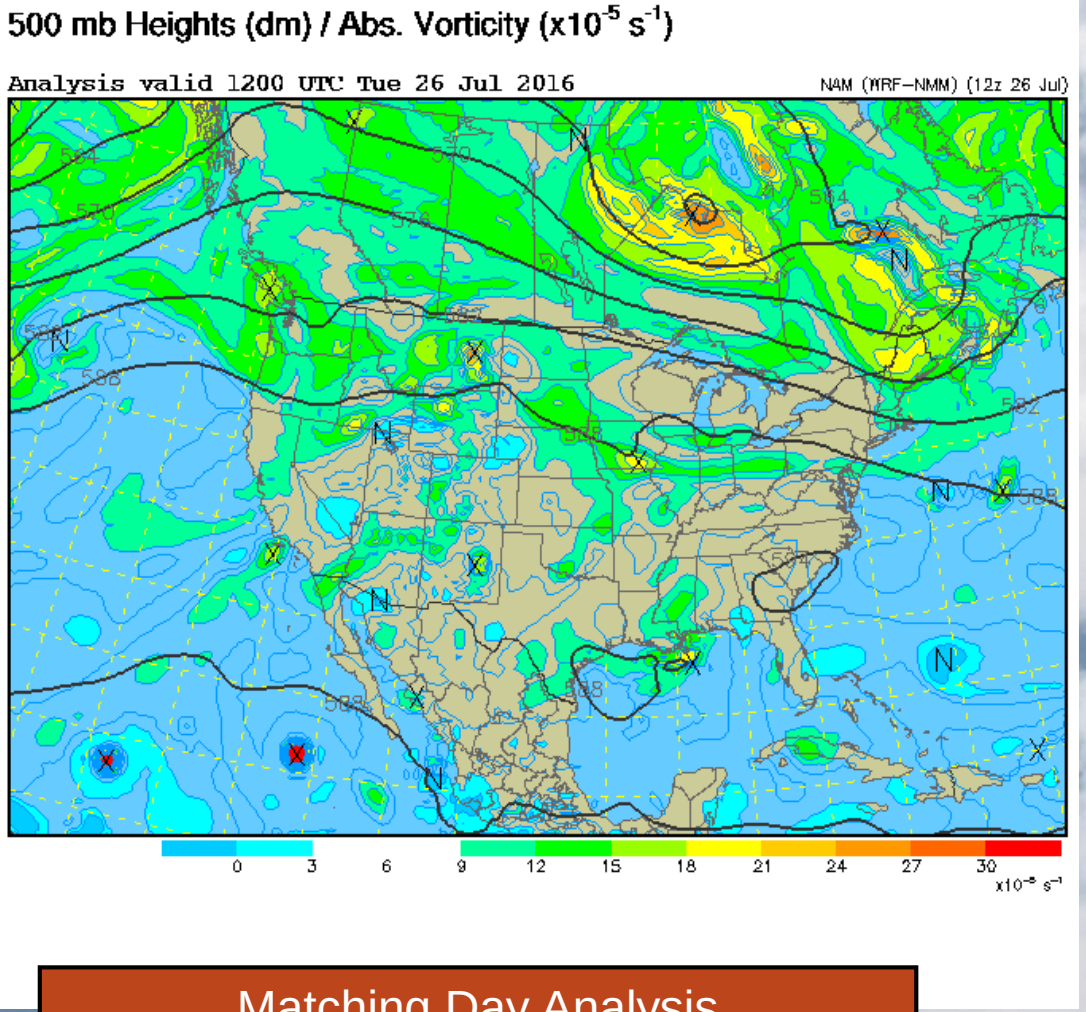
Narragansett 42 ppb

West Greenwich 39 ppb

TF Green High Temp 92F



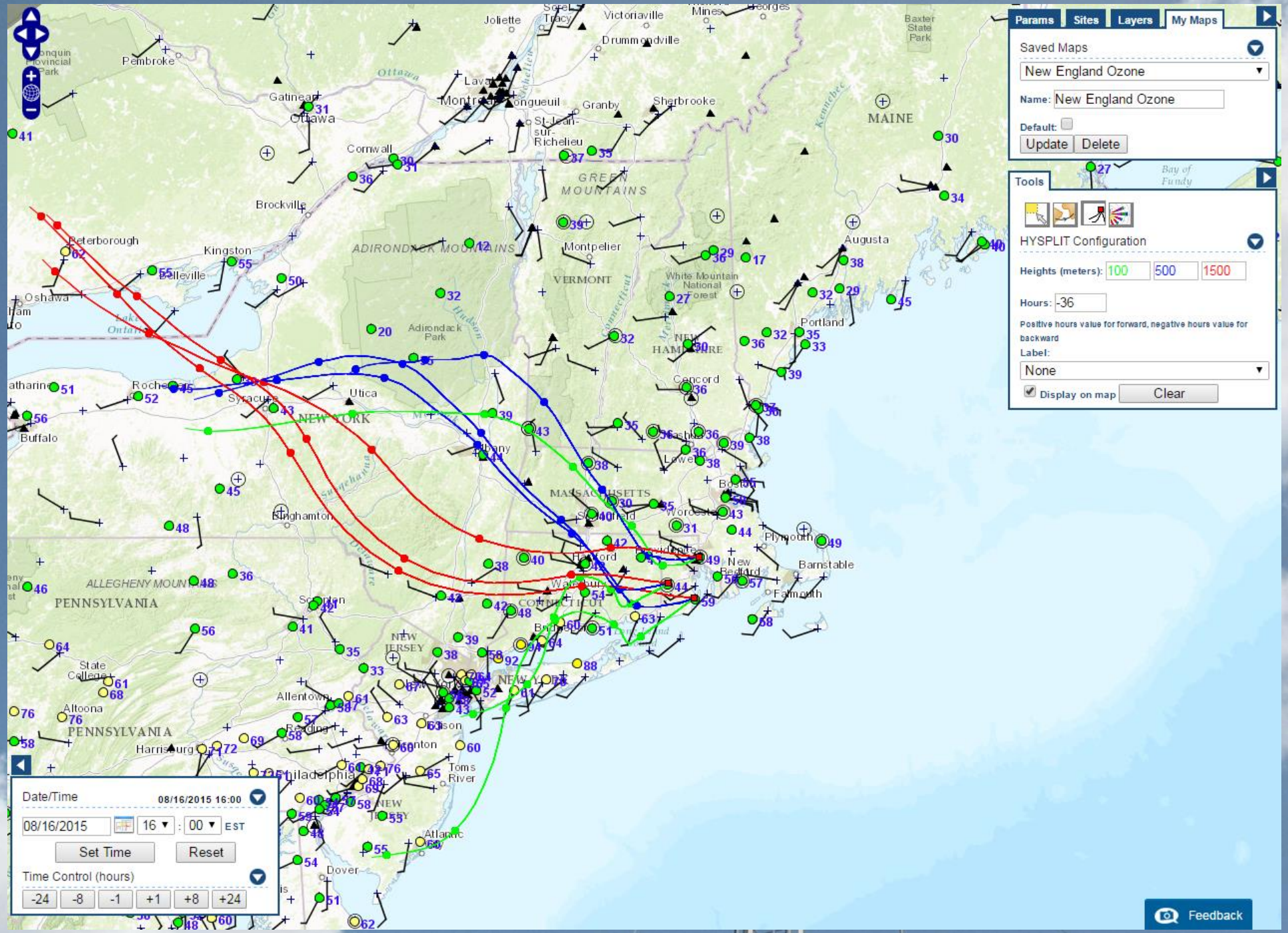




Matching Day Analysis

7/26/2016

Trough axis to the east of Rhode Island.
NW flows at 500 mb, WNW flows at 850 mb
Cold front west of Rhode Island. Partly cloud skies, no precipitation.



Matching Day Analysis

8/16/2015

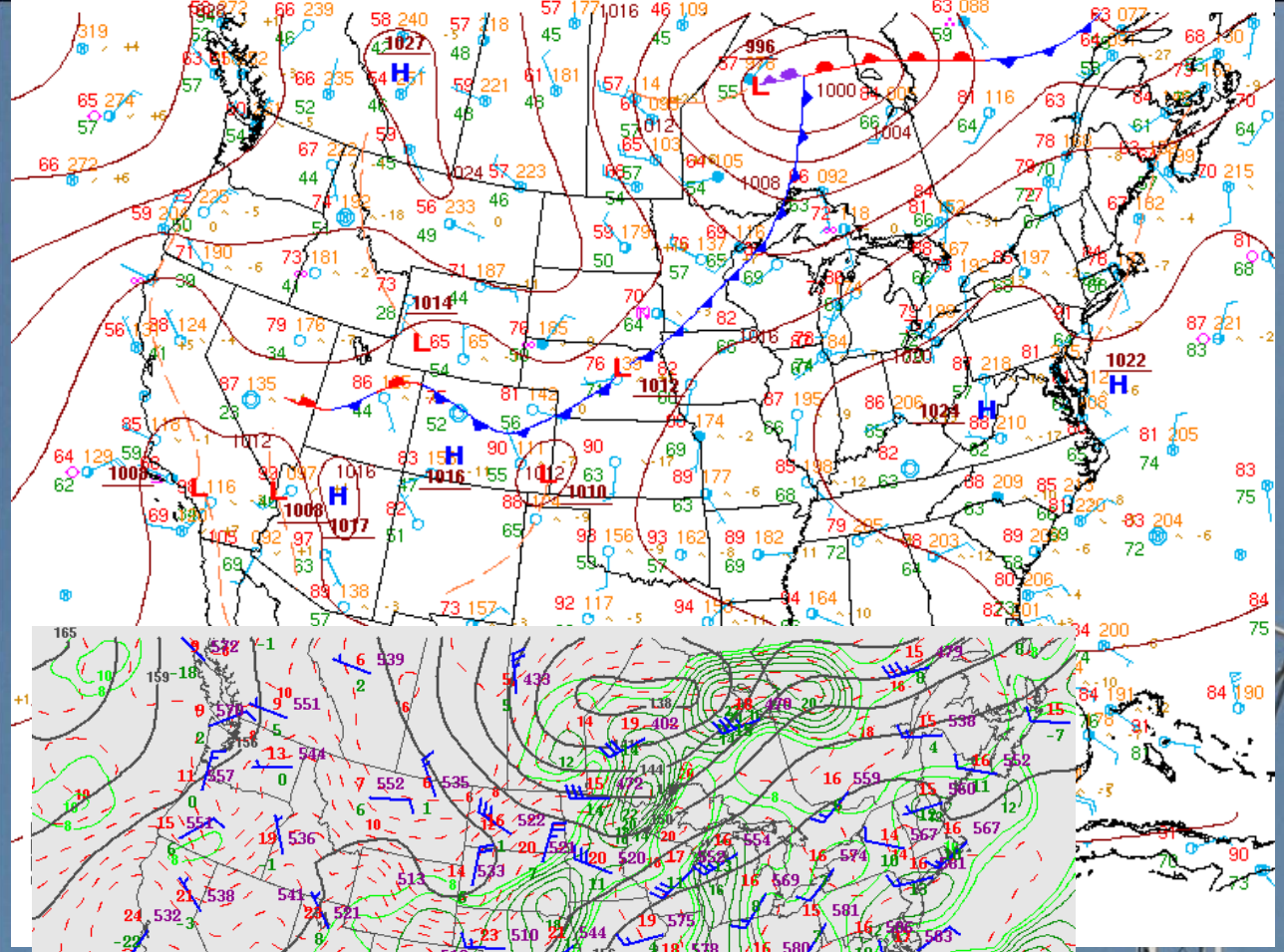
Max 8-hr Ozone

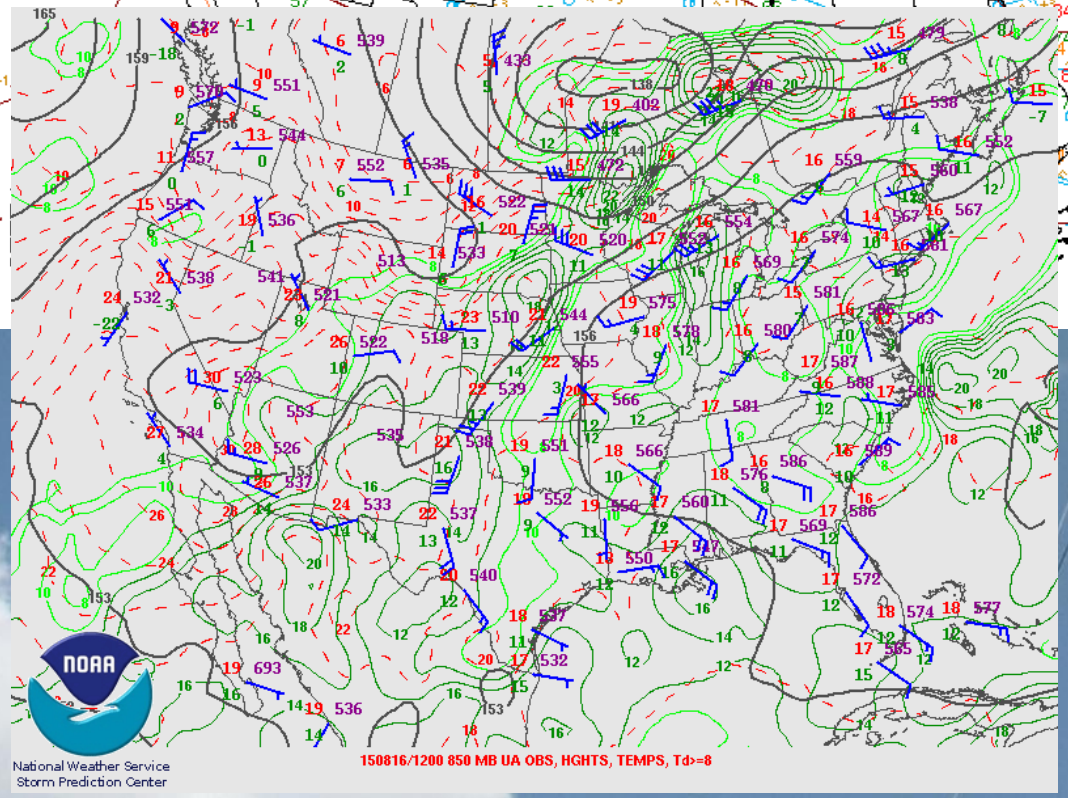
East Providence 48 ppb

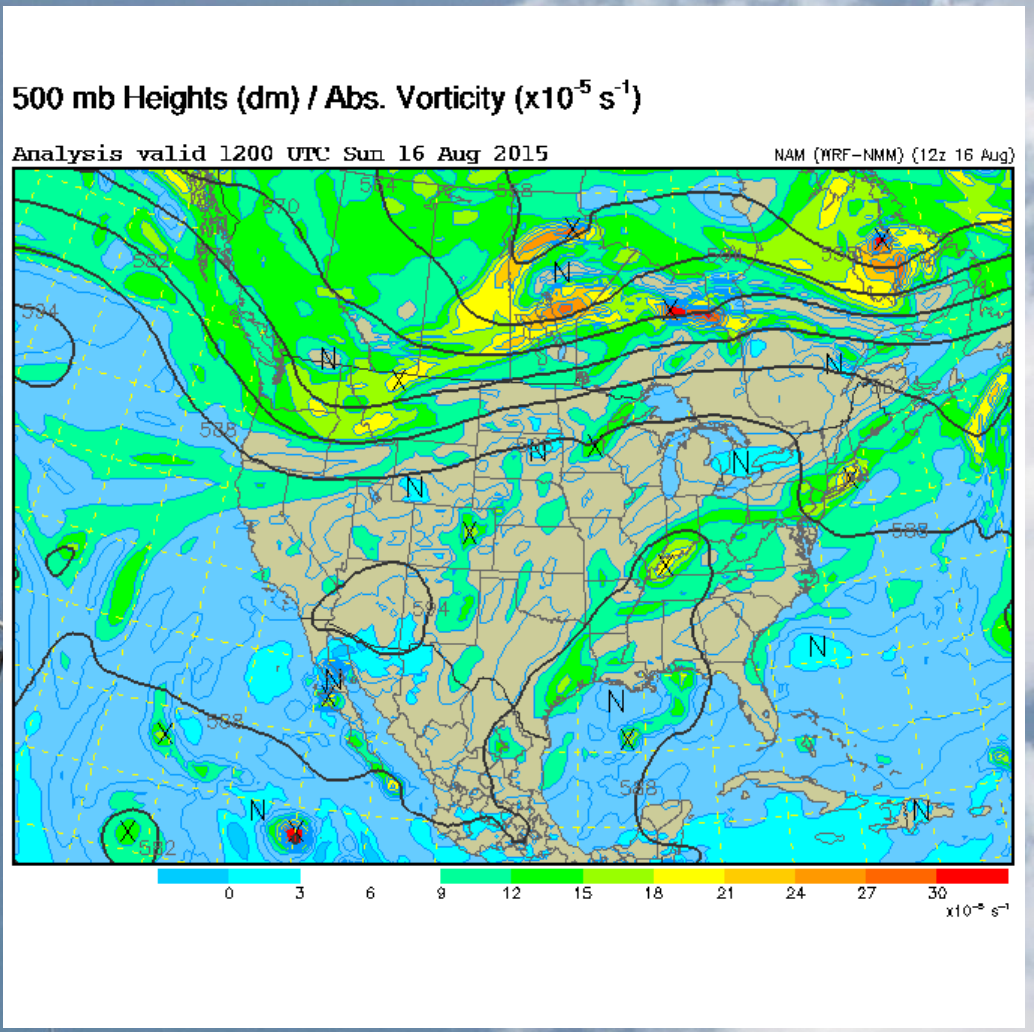
Narragansett 67 ppb

West Greenwich 44 ppb

TF Green High Temp 91F







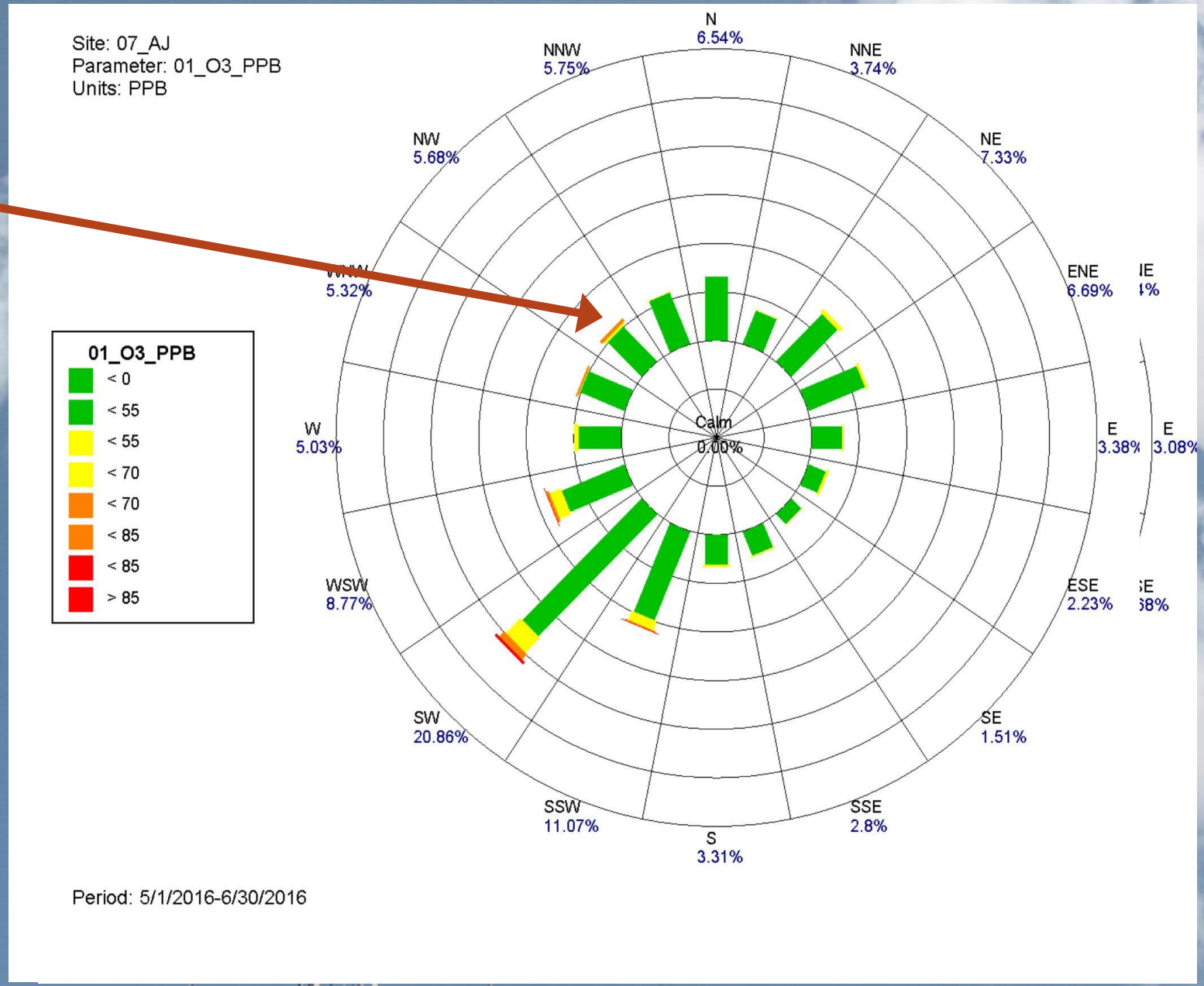
Matching Day Analysis

8/16/2015

850 and 500 mb flows NW. A bit more variable at the surface but still some showing NW on trajectory analysis. Trough at 500 mb and 850 mb, in vicinity of RI.

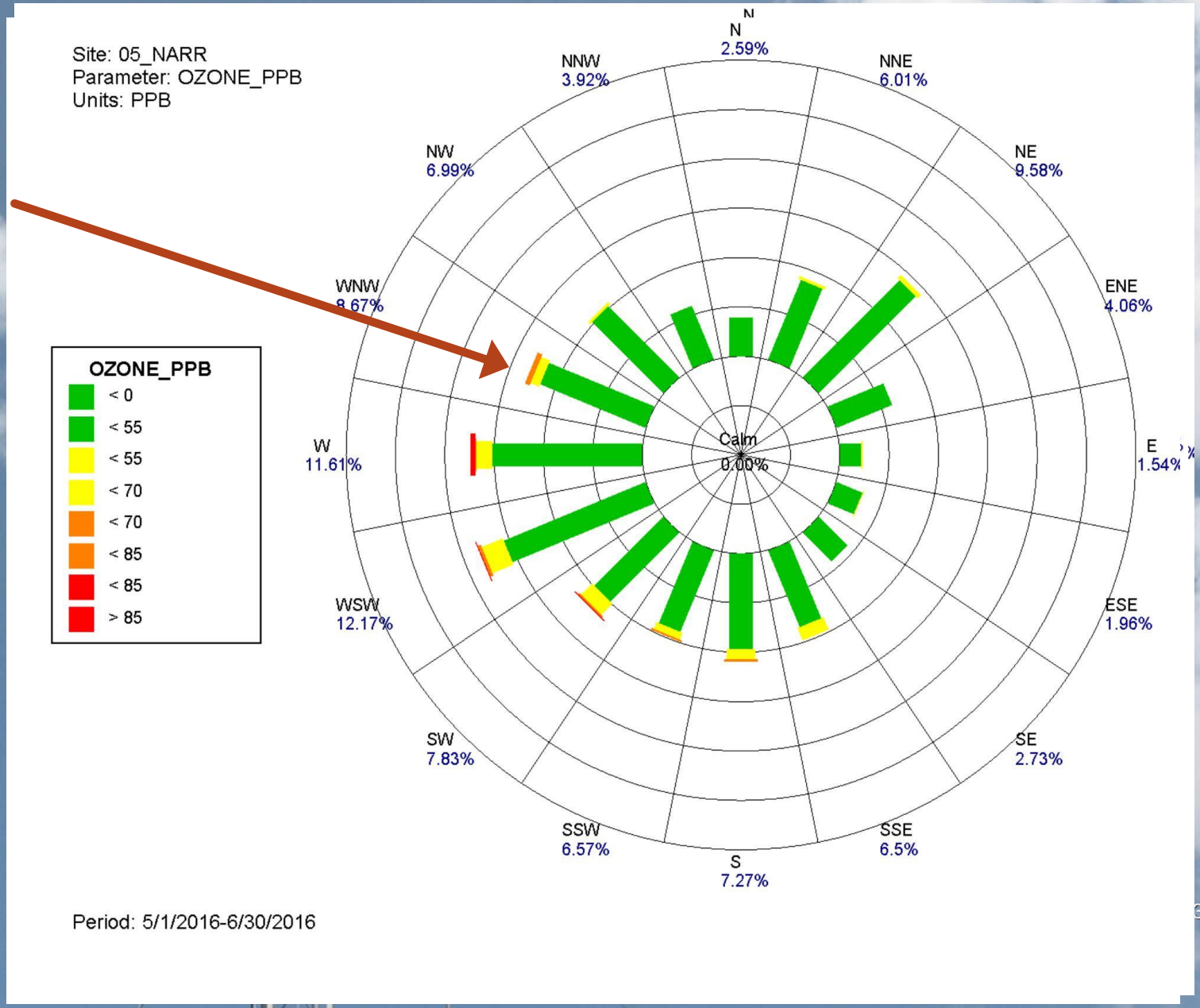
West Greenwich Pollution Roses 2014-2016

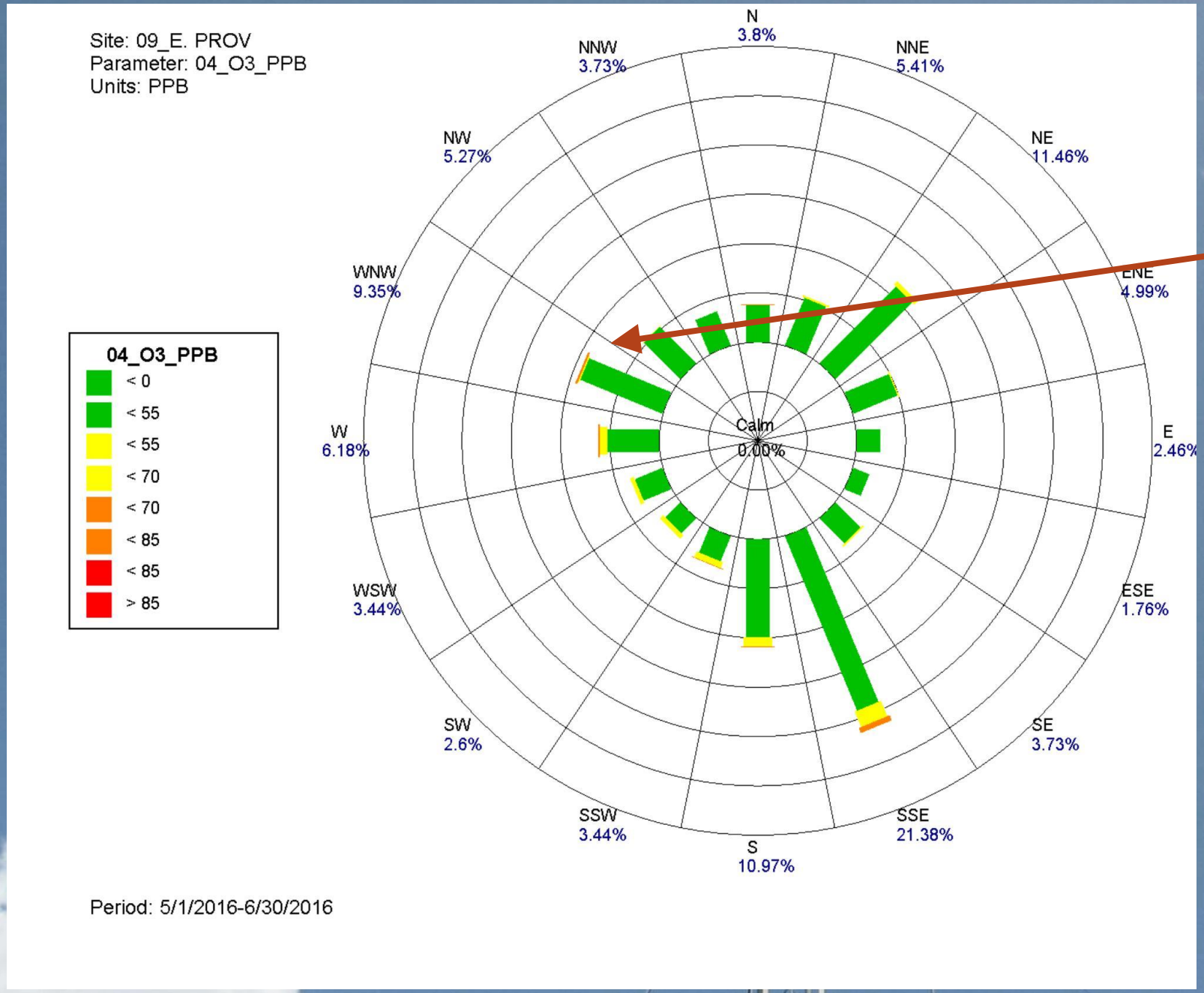
High Ozone surface wind component typically from favorable transport directions SW, WSW, as per 2014 and 2015. Rose for 2016 shows unusual elevated ozone with NW component.



Narragansett Pollution Roses 2014-2016

High Ozone surface wind component typically from favorable transport directions of W, SW and WSW, as per 2014 and 2015. 2016 shows unusual elevated ozone from NW component.





East Providence Pollution Roses 2014-2016

This location is frequently impacted by sea breezes in spring time. High ozone event was limited on 5/26 due to sea breeze wind shift.

	Ozone ppb	VWD degrees	Direction	VWS
5/26/2016 8:00	60	17	NNE	2
5/26/2016 9:00	70	9	Calm	1
5/26/2016 10:00	76	274	W	2
5/26/2016 11:00	85	213	SW	2
5/26/2016 12:00	79	171	SSE	3
5/26/2016 13:00	74	163	SSE	4
5/26/2016 14:00	76	157	SE	5
5/26/2016 15:00	78	161	SSE	4
5/26/2016 16:00	77	164	SSE	3
5/26/2016 17:00	76	159	SE	3
5/26/2016 18:00	81	156	SE	3
5/26/2016 19:00	80	156	SE	3
5/26/2016 20:00	73	159	SSE	2
5/26/2016 21:00	65	159	SSE	2

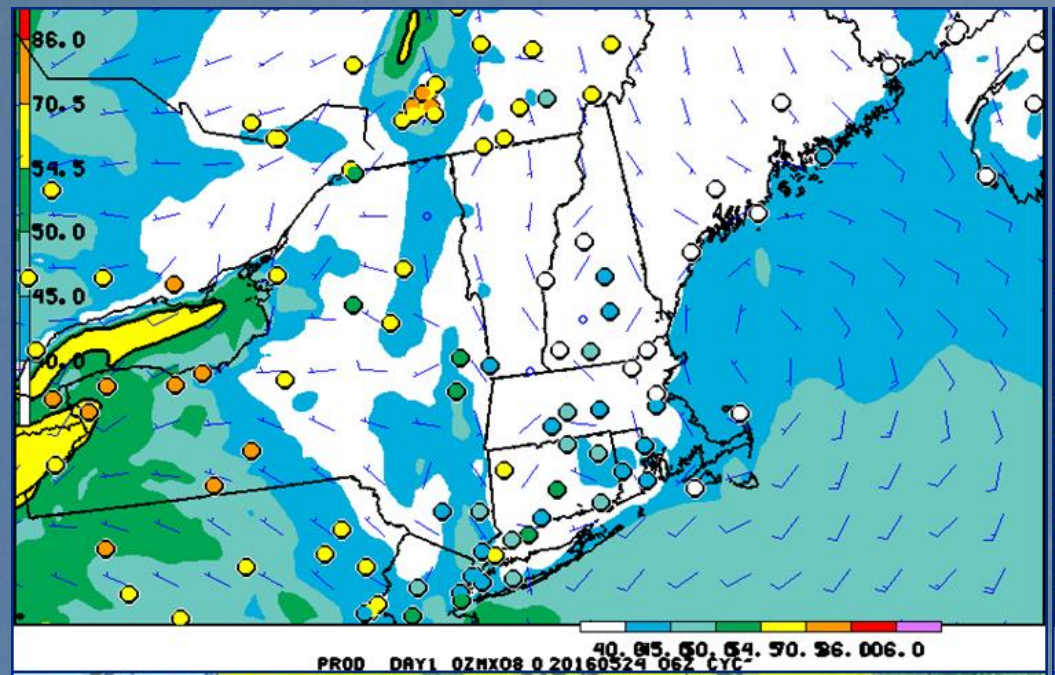
East Providence SSE to SE sea breeze starting at 12PM on 5/26 limited ozone exceptional event due to the influence of cleaner marine air. West Greenwich and Narragansett were not influenced by sea breeze.

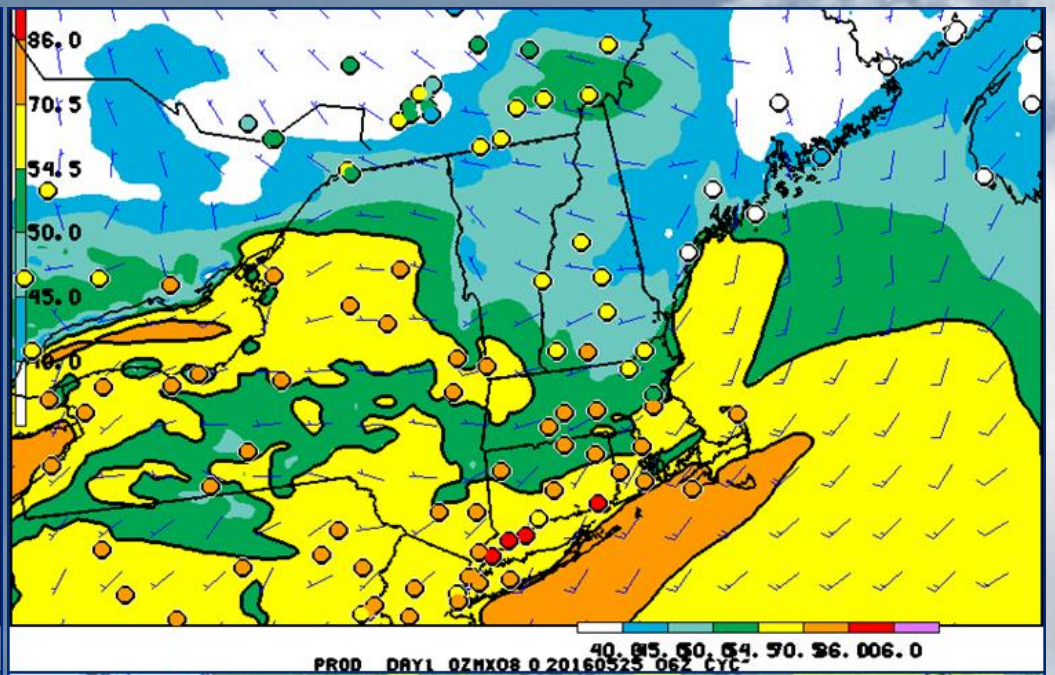
	Ozone ppb	VWD degrees	Direction	VWS
5/26/2016 8:00	62	32	NE	1
5/26/2016 9:00	72	287	WNW	3
5/26/2016 10:00	81	316	NW	2
5/26/2016 11:00	83	316	NW	2
5/26/2016 12:00	84	256	WSW	4
5/26/2016 13:00	84	238	SW	6
5/26/2016 14:00	86	230	SW	5
5/26/2016 15:00	86	219	SW	5
5/26/2016 16:00	87	233	SW	5
5/26/2016 17:00	87	206	SSW	2
5/26/2016 18:00	80	216	SW	1
5/26/2016 19:00	67	265	WSW	0
5/26/2016 20:00	53	346	NW	calm
5/26/2016 21:00	42	324	NW	calm

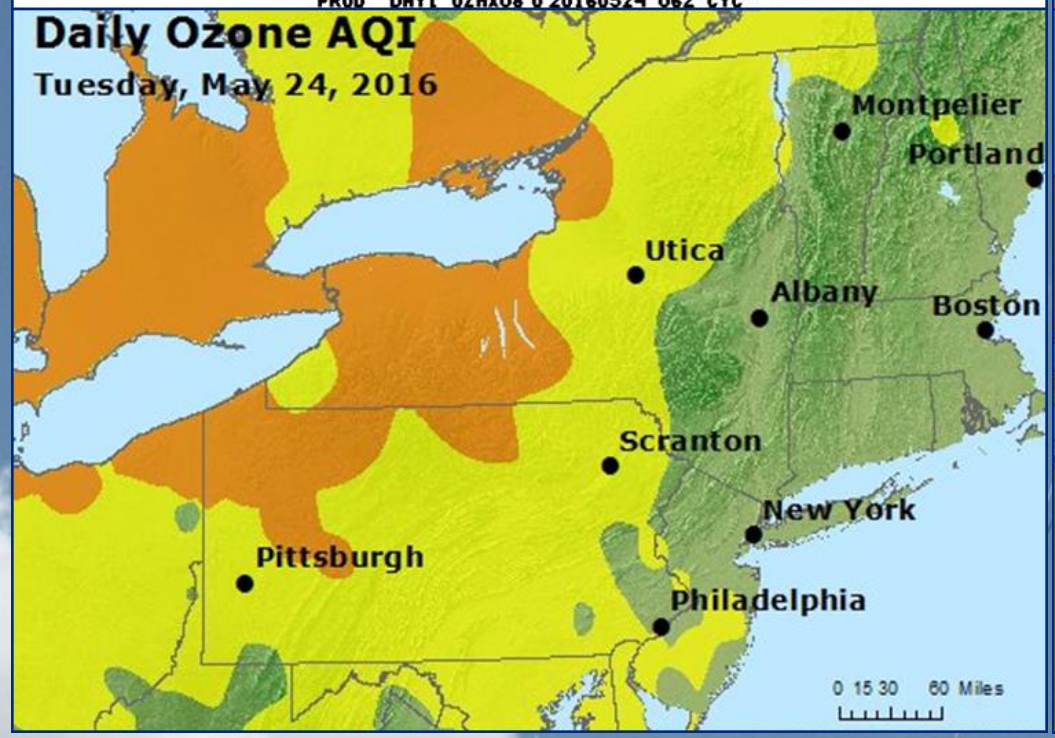
Narragansett winds remained from a westerly component all day. No sea breeze. Ozone readings remained high.

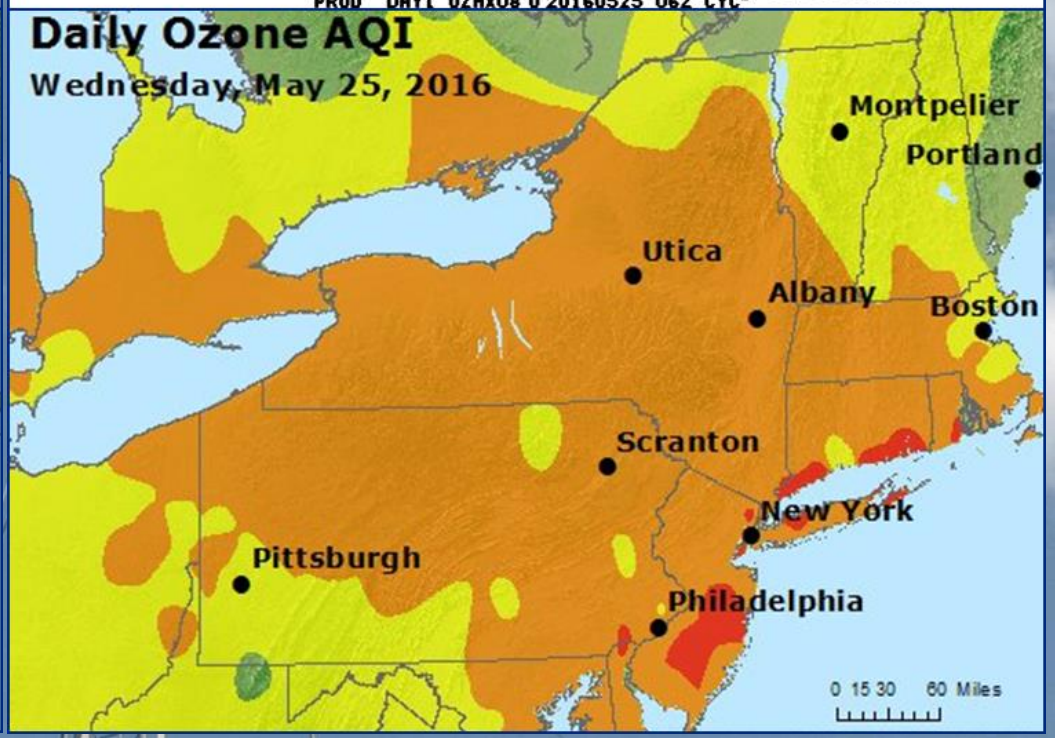
	Ozone ppb	VWD degrees	Direction	VWS
5/26/2016 8:00	56	104	E	2.4
5/26/2016 9:00	59	180	S	3.4
5/26/2016 10:00	69	163	SSE	3.6
5/26/2016 11:00	78	183	S	5.7
5/26/2016 12:00	79	186	S	6.7
5/26/2016 13:00	80	200	SSW	5.3
5/26/2016 14:00	79	211	SW	4.5
5/26/2016 15:00	83	220	SW	4.1
5/26/2016 16:00	91	240	SW	4.9
5/26/2016 17:00	87	237	SW	3.8
5/26/2016 18:00	80	246	WSW	4
5/26/2016 19:00	71	254	WSW	3.7
5/26/2016 20:00	65	260	WSW	4.8
5/26/2016 21:00	63	265	W	4.9

West Greenwich did not experience sea breeze with a westerly component during peak ozone hours.



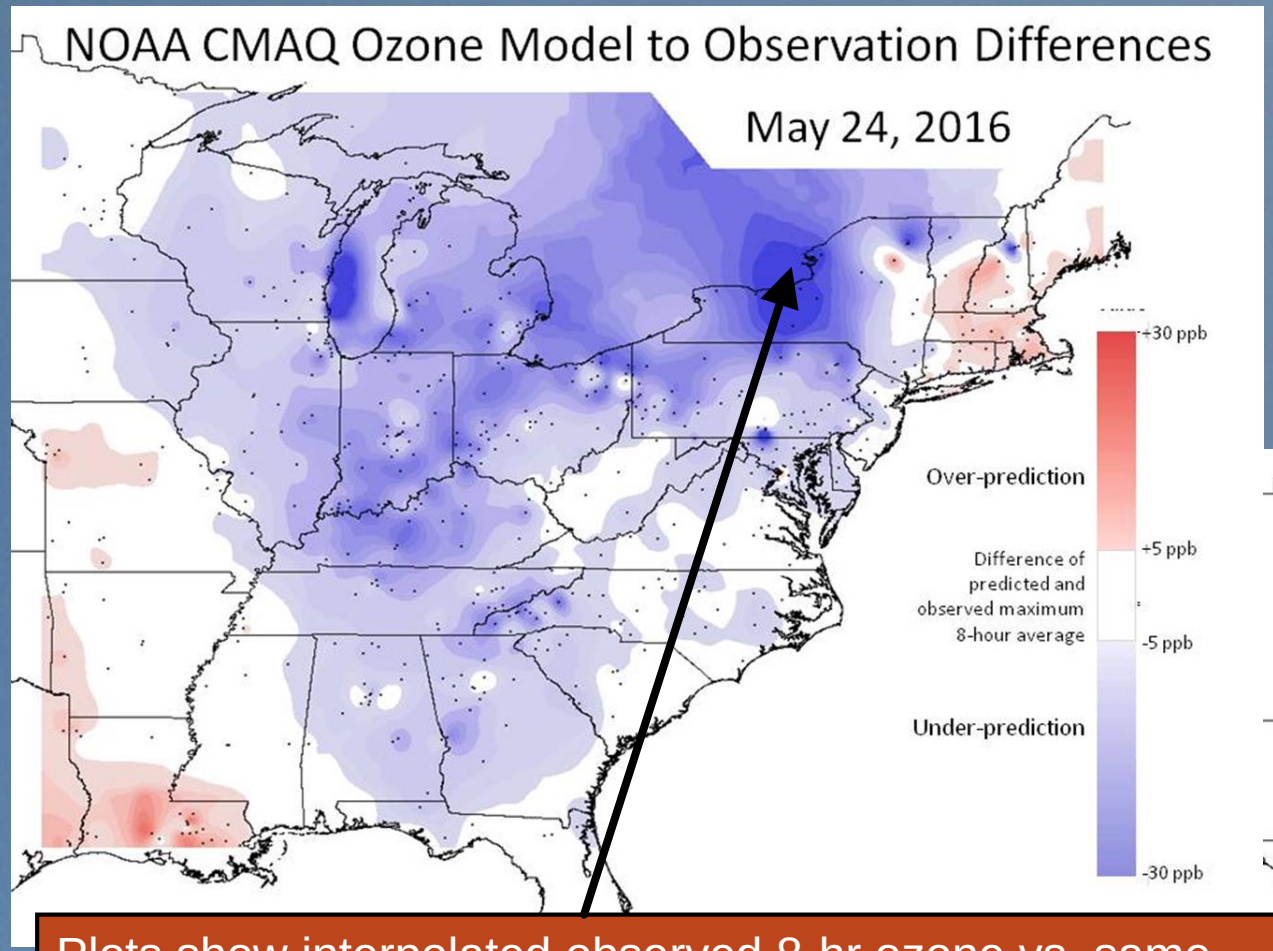


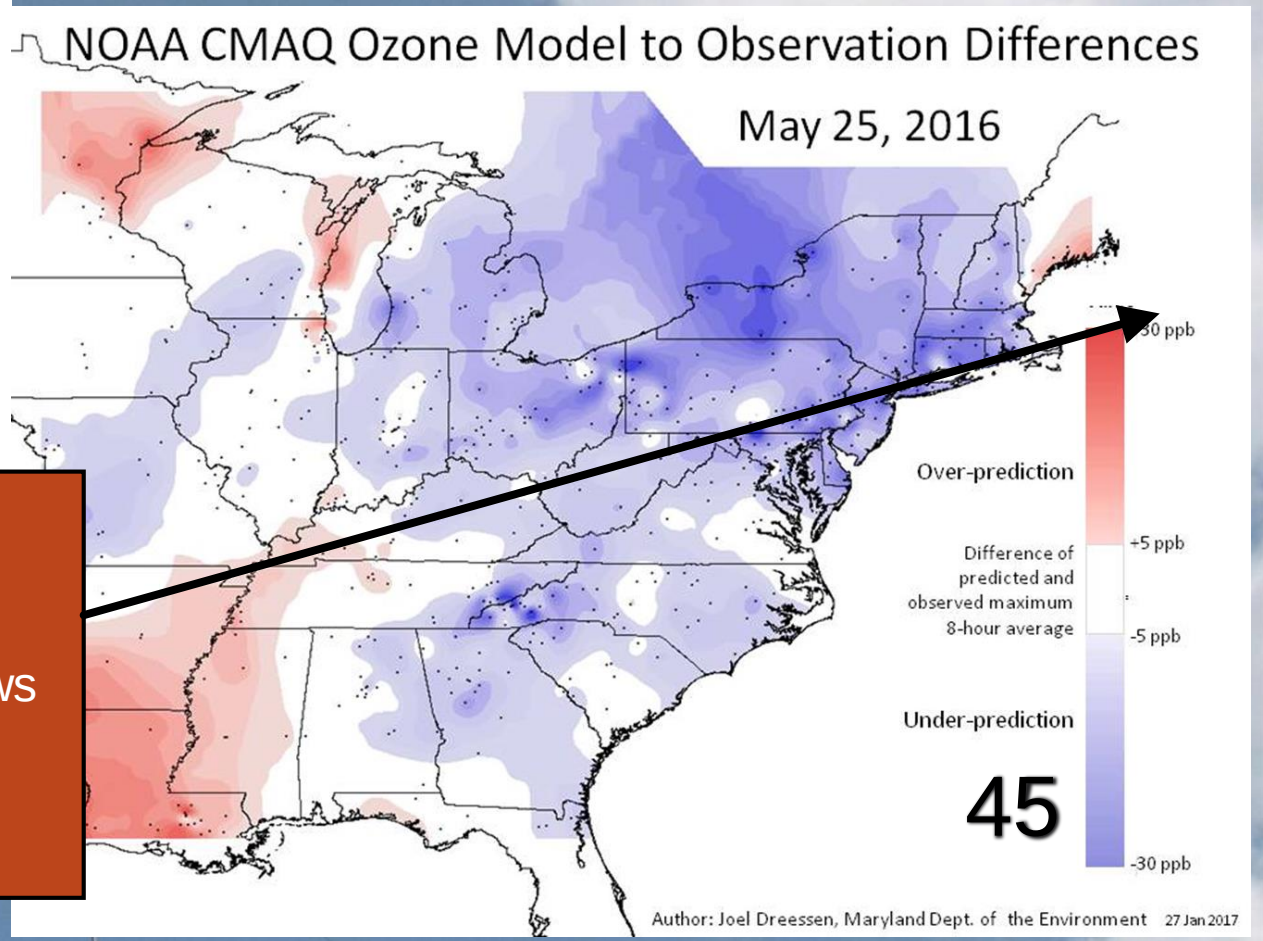




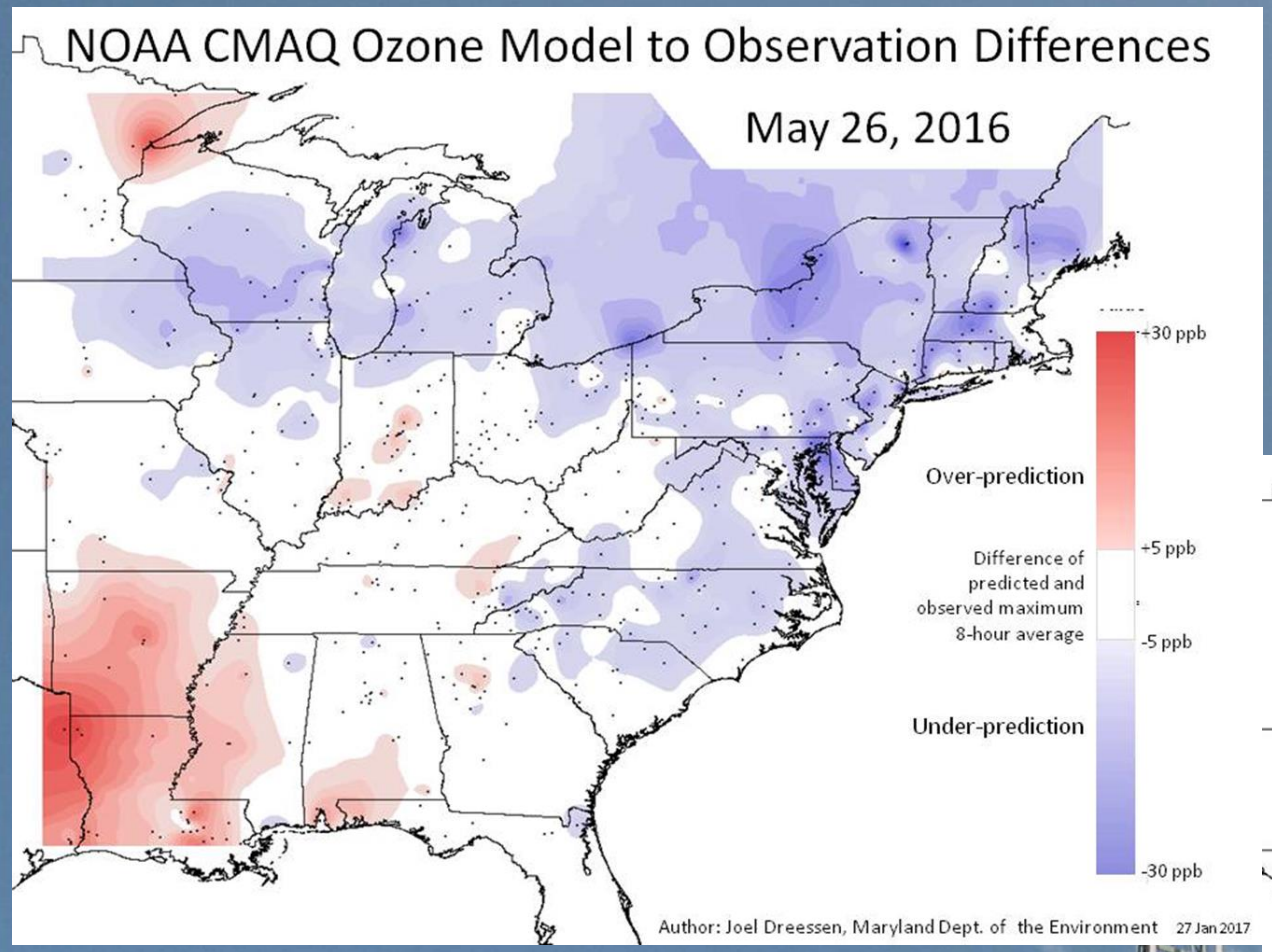
NOAA Model vs AQI Observed

Model (top) was vastly under predicting ozone (bottom) from smoke event.





Plots show interpolated observed 8-hr ozone vs. same day NOAA CMAQ model. NOAA CMAQ model does NOT assimilate gaseous smoke emissions in predicting ozone concentrations. A substantial negative bias follows smoke plume on 5/24/16 with a clear negative bias in RI of 15-25 ppb on 5/25/16. Courtesy of Joel Dreesen (Maryland DE).



Negative model bias and under prediction continues on 5/26/16 with smoke impact. Bias becomes more neutral on 5/27/16 as smoke plume is transported out of the region.